United States
Department of
Agriculture

Forest Service

**Pacific
Northwest
Region**

June 1985

Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington

Part 1 – Chapter Narratives

Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington

Part 1 – Chapter Narratives

E. Reade Brown
Technical Editor

U.S. Department of Agriculture
Forest Service
Pacific Northwest Region

Published in cooperation with the
U.S. Department of the Interior
Bureau of Land Management

June 1985

Prepared in Information Office of
Pacific Northwest Region, Forest Service,
U.S. Department of Agriculture, Portland, OR
Publication No.: R6-F&WL-192-1985

Art Director: Gail Saunders
Library of Congress Catalog Card No.: 85-601383
For sale by the Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402

Stock No. 001-001-00616-5

Authors

Robert J. Anderson; B.S. (Zoology), M.S. (Forest Science); Wildlife Research Biologist, Weyerhaeuser Company, Tacoma, Washington.

Neil B. Armantrout; B.S. (Zoology), M.S. (General Science), Ph.D. (Fisheries Biology); District Fisheries Biologist, Department of the Interior, Bureau of Land Management, Eugene, Oregon.

Ronald Bartels; B.S. (Wildlife Management); Assistant Regional Supervisor, Oregon Department of Fish and Wildlife, Roseburg, Oregon.

Scott L. Benson; B.A. (Aquatic Biology); Hewlett Packard Corporation, Roseville, California. Formerly: Oregon State University, Marine Science Center, Newport, Oregon.

Virgil W. Binkley; B.S. (Forest Management), M.S. (Logging Engineering); Leader, Helistat/Logging Systems, USDA, Forest Service, Pacific Northwest Region, Portland, Oregon.

Larry W. Brewer; B.S. (Fisheries and Wildlife Biology), M.S. (Wildlife Science); Wildlife Research Biologist, Washington Department of Game, Stanwood, Washington.

E. Reade Brown; B.S. (Forestry - Range and Game Management), M.S. (Forestry – Wildlife Management); Chief, Wildlife Management, Washington Department of Game, Olympia, Washington, (Retired).

Charles Bruce; B.S. (Biology), B.S. (Wildlife Science); Regional Non-Game Biologist, Oregon Department of Fish and Wildlife, Corvallis, Oregon.

Christopher Carey; B.S.(Wildlife Science); Research Biologist, Oregon Department of Fish and Wildlife, Forest Grove, Oregon.

Steven P. Cline; B.S. (Forestry); M.S. (Forest Science); Research Assistant, Department of Forest Science, Oregon State University, Corvallis, Oregon.

Jim A. Collins; B.S. (Wildlife Management); Regional Non-Game Biologist, Oregon Department of Fish and Wildlife, Roseburg, Oregon.

Robert A. Corthell; B.S., M.S. (Fish and Game Management); Biologist, USDA, Soil Conservation Service, Oregon State Office, Portland, Oregon, (Retired).

Alan B. Curtis; B.S. (Forest Management); Forester/Botanist, U.S. Department of the Interior, Bureau of Land Management, Eugene, Oregon.

John D. Dell; B.S. (Forestry); Fuels Management Specialist, USDA, Forest Service, Pacific Northwest Region, Portland, Oregon (Retired).

Fredrick C. Dobler; B.S., M.S. (Zoology); Research Wildlife Biologist, Washington Department of Game, Olympia, Washington.

Dan Edwards; B.A. (Biological Science); B.S., M.S. (Wildlife Science); (Fish and Wildlife Technician, Oregon Department of Fish and Wildlife, Corvallis, Oregon.

Fred H. Everest; B.S., M.S., Ph.D. (Fisheries); Supervisory Research Fishery Biologist, USDA, Forest Service, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, Corvallis, Oregon.

Larry B. Everson; B.S. (Fish and Wildlife Management), M.S. (Fisheries and Water Pollution); Fishery Biologist, Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Portland, Oregon.

David Fauss; B.S., M.S. (Forest Management); Inventory Specialist, U.S. Department of the Interior, Bureau of Land Management, Coos Bay, Oregon.

Eric D. Forsman; B.S. (Wildlife Science), M.S., Ph.D. (Wildlife Biology); Wildlife Consultant, 580 S.E. Corliss Ave., Corvallis, Oregon.

Jerry F. Franklin, B.S., M.S. (Forest Management), Ph.D. (Botany); Chief Plant Ecologist, USDA, Forest Service, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, Corvallis, Oregon.

Thomas F. Gaumer; B.S. (Fisheries); Fish and Wildlife Biologist, Oregon Department of Fish and Wildlife, Newport, Oregon.

Frederick C. Hall; B.S. (Forest Management), M.S. (Range Management), Ph.D. (Plant Ecology); Regional Ecologist, USDA, Forest Service, Pacific Northwest Region, Portland, Oregon.

Edmund P. Harshman; B.S. (Forestry), M.S. (Range Management); Wildlife Biologist, USDA, Forest Service, Willamette National Forest, Eugene, Oregon.

Gordon N. Haugen; B.S., M.S. (Fish and Wildlife Management); Regional Fishery Biologist, USDA, Forest Service, Pacific Northwest Region, Portland, Oregon.

David A. Heller; B.S. (Zoology), M.S. (Biology); Forest Fishery Biologist, USDA, Forest Service, Mt. Hood National Forest, Portland, Oregon.

Gene Herb; B.S. (Wildlife Management); District Wildlife Biologist, Oregon Department of Fish and Wildlife, Forest Grove, Oregon.

Barbara L. Holder; B.S., M.S. (Biology); Director of Wildlife and Fisheries, Northern Region, USDA, Forest Service, Missoula, Montana. Formerly: Endangered Species Coordinator, USDA, Forest Service, Pacific Northwest Region, Portland, Oregon.

Kirk M. Horn; B.S., M.S. (Zoology); Regional Wildlife Biologist, USDA, Forest Service, Pacific Northwest Region, Portland, Oregon.

Jack C. Howerton; B.S. (Wildlife Science); Northwest Power Planning Coordinator, Washington Department of Game, Olympia, Washington.

James M. Johnston; B.S., M.S. (Fisheries Management); Assistant Director, Administration, Washington Department of Game, Olympia, Washington.

Steven M. Keller; B.S. (Fisheries Management); Area Supervisor, Environmental Planning, Washington Department of Fisheries, Olympia, Washington.

Richard L. Knight; B.S. (Wildlife Ecology), M.S. (Wildlife Science), Ph.D. (Wildlife Ecology); Wildlife Biologist, Department of Wildlife Ecology, University of Wisconsin, Madison, Wisconsin. Formerly: Non-Game Biologist, Washington Department of Game, Olympia, Washington.

Mike P. Kuttel; B.S. (Wildlife Science); Regional Administrator, Washington Department of Game, Aberdeen, Washington.

Wayne Logan; B.S. (Wildlife Science); Wildlife Biologist, U.S. Department of the Interior, Bureau of Land Management, Salem, Oregon.

Dean Longrie; B.S. (Botany), M.S., Ph.D. (Wildlife Ecology); Forest Wildlife Biologist, USDA, Forest Service, Mt. Hood National Forest, Gresham, Oregon.

Ira D. Luman; B.S. (Fish and Game Management); Wildlife Biologist, U.S. Department of the Interior, Bureau of Land Management, Oregon State Office, Portland, Oregon, (Retired).

Charles McComb; B.S. (Forestry); Wildlife Forester, Washington Department of Game, Colville, Washington.

Anita McMillan; B.S. (Wildlife Science); Wildlife Consultant, McMillan's Environmental Research, Vancouver, Washington.

R. William Mannan; B.A. (Biology), M.S., Ph.D. (Wildlife Ecology); Assistant Professor, Wildlife Ecology, School of Renewable Resources, University of Arizona, Department of Fisheries and Wildlife, Tucson, Arizona. Formerly: Research Assistant, Oregon Cooperative Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

Bruce G. Marcot; B.S. (Natural Resources), M.S. (Natural Resources-Wildlife Management); Research Assistant, Oregon Cooperative Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

Kim Mellen; B.S. (Wildlife Sciences); Graduate Research Assistant, Oregon Cooperative Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

Gerald W. Mires; B.S. (Wildlife Science); Wildlife Biologist, U.S. Department of the Interior, Bureau of Land Management, Roseburg, Oregon.

William A. Neitro; B.A. (Conservation-Wildlife Management); Wildlife Biologist, U.S. Department of the Interior, Bureau of Land Management, Oregon State Office, Portland, Oregon.

Thomas E. Nickelson; B.S., M.S. (Fisheries); Research Project Leader, Oregon Department of Fish and Wildlife, Research Division, Corvallis, Oregon.

Art L. Oakley; B.S. (Fish and Game Management), M.S. (Fisheries); Fishery Biologist, U.S. Department of the Interior, Bureau of Land Management, Oregon State Office, Portland, Oregon.

Laimons Osis; B.S. (Biology); Fish and Wildlife Biologist, Oregon Department of Fish and Wildlife, Newport, Oregon.

Tom Owens; B.S., M.S. (Wildlife Biology); Supervisor, Non-Game Data System, Washington Department of Game, Olympia, Washington.

William D. Parante; B.S. (Fisheries Management); Fisheries Management Biologist, U.S. Fish and Wildlife Service, Vancouver, Washington, (Deceased).

James A. Rochelle; B.S., M.S. (Wildlife Biology), Ph.D. (Forest Wildlife Ecology); Forest Wildlife Biologist, Weyerhaeuser Company, Tacoma, Washington.

William Ruediger; B.S. (Wildlife Management), M.F. (Forest Management); Wildlife Biologist, USDA, Forest Service, Gifford Pinchot National Forest, Vancouver, Washington.

Gail Schaefer; B.S. (Forestry and Recreation Resource Management); Assistant Area Manager, U.S. Department of the Interior, Bureau of Land Management, Medford, Oregon. Formerly: Forester, U.S. Department of the Interior, Bureau of Land Management, Oregon State Office, Portland, Oregon.

Raymond W. Scharpf; B.A. (Conservation-Wildlife Management); Resource Assistant/Supervisory Wildlife Biologist, USDA, Forest Service, Gifford Pinchot National Forest, Packwood Ranger District, Packwood, Washington.

James R. Sedell; B.A. (Philosophy and Political Science), Ph.D. (Biology); Research Ecologist, USDA, Forest Service, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, Corvallis, Oregon.

Delbert G. Skeesick; B.S., M.S. (Fisheries); Forest Fisheries Biologist, USDA, Forest Service, Willamette National Forest, Eugene, Oregon.

Doug Smithey; B.S. (Biology), M.S. (Wildlife Management); District Wildlife Biologist, U.S. Department of the Interior, Bureau of Land Management, Coos Bay, Oregon.

Mark V. Stalmaster; B.S. (Wildlife Biology), M.S. (Applied Biology), Ph.D. (Biology-Ecology); Wildlife Consultant, 10,000 47th Avenue, SW, Seattle, Washington.

Richard M. Starr; B.S. (Environmental Sciences), M.S. (Physical Geography); Fish and Wildlife Biologist, Oregon Department of Fish and Wildlife, Newport, Oregon.

Harold Sturgis; B.S. (Wildlife Management); District Wildlife Biologist, Oregon Department of Fish and Wildlife, Corvallis, Oregon.

Douglas Taylor; B.S. (Wildlife Management); District Wildlife Biologist, Oregon Department of Fish and Wildlife, Tillamook, Oregon.

Robert E. Vincent; B.S. (Wildlife Management), M.S. (Fishery Biology), Ph.D. (Ecology); Wildlife Biologist, Philomath, Oregon.

Frank F. Wagner; B.S. (Wildlife Management); U.S. Department of the Interior, Bureau of Land Management, Eugene, Oregon.

Jay F. Watson; B.S. (Wildlife Science), M.S., Ph.D. (Fisheries Biology); Supervisor, Technical Services, U.S. Fish and Wildlife Service, Portland, Oregon.

Richard L. Werner; B.S. (Wildlife Management); District Wildlife Biologist, Oregon Department of Fish and Wildlife, Central Point, Oregon.

Herbert L. Wick; B.S. (Forest Management), M.F. (Silviculture); District Ranger, Rigdon Ranger District, Willamette National Forest, Oakridge, Oregon.

Mike Wisdom; B.S. (Wildlife Management), M.S. (Wildlife Biology); Wildlife Biologist, U.S. Department of the Interior, Bureau of Land Management, Coos Bay, Oregon.

Gary W. Witmer; B.S., M.S. (Biology), M.S. (Wildlife Ecology), Ph.D. (Wildlife Science); Wildlife Ecologist, Argonne National Laboratory, Argonne, Illinois. Formerly: Area Wildlife Biologist, Washington Department of Game, Vancouver, Washington.

Ray Zalunardo, B.S. (Fish and Wildlife Management), M.S. (Wildlife Management); Wildlife Biologist, Umpqua National Forest, Roseburg, Oregon.

Preface

In the spring and summer of 1865 Samuel Bowles, noted editor of the Springfield, Massachusetts *Republican,* traveled across the continent including the western portions of the new State of Oregon and the Territory of Washington. In his account of this adventure, Bowles (*Across the Continent,* New York; Hurd and Houghton Publishers. 1865. p. 205.) made the following statement about the budding timber industry: "The business is but in its infancy; it will grow with the growth of the whole Pacific Coast, . . . for it is impossible to calculate the time when, cut and saw as we may, all these forests shall be used up, and the supply become exhausted." Although the timber supply is certainly not exhausted, in the managed forests of western Oregon and Washington we have reached the point 120 years later, at which we can calculate the end of virgin timber stands as Mr. Bowles and his party observed them.

Timber harvest has major impacts on many resources including wildlife and fish, but only in recent years has attention been focused on these impacts. In the past foresters have concentrated their attention on the harvest and regeneration of merchantable timber, whereas biologists have devoted their time to wildlife and fish species that were of major economic or esthetic importance. Neither biologists nor foresters looked at the ecosystem as a whole or as to how the various components related to one another.

With rapidly expanding human populations and their demands for space and resources, has come an increasing awareness that there is a finite land base that must furnish both. Concerns have developed that involve all wildlife species, not just those that are popular with hunters and fishermen or the viewing public. Laws have been changed and new laws have been passed, particularly directed at the public sector, that require the land manager to consider all resources when management plans for a particular land base are being developed. Words such as "ecology," "environment," "ecosystems," and "habitat diversity" were seldom heard a few years ago, but they are now common and the public has at least a general understanding of their meanings.

Because of increased public awareness of environmental concerns and new laws and regulations that require broader consideration for all resources, managers are demanding better information for making land use decisions. Many people recognized the need for complete information concerning the effects of timber management activities on all species of wildlife and their habitat. One of the first and most complete attempts to put this type of information together was carried out by Jack Ward Thomas and a group of dedicated biologists in southeastern Washington and northeastern Oregon. Their publication, "Wildlife Habitats in Managed Forests - The Blue Mountains of Oregon and Washington" (Jack Ward Thomas, Technical Editor) presented an idea whose time had come, and similar efforts are being undertaken across the country.

Recognizing that their basic approach had broad application, Leon Murphy, Director of Fish and Wildlife for the U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; Robert Stein, Assistant Director – Wildlife for the Oregon Department of Fish and Wildlife; and Robert Borovicka, Chief, Branch of Range, Watershed, and Wildlife for the U.S. Department of the Interior, Bureau of Land Management, Oregon State Office developed plans for a similar project for the forested lands of

western Oregon and western Washington. The Oregon-Washington Interagency Wildlife Committee, an ad hoc group consisting of administrators representing most State and Federal agencies working with wildlife in the Pacific Northwest, obtained approval and funding from the concerned agencies to launch a cooperative project designed to develop the needed information. Problems were identified and interagency teams of professionals with expertise in those areas were assigned. Where actual research data were not available, authors were requested to use their best judgement and that of their peers to predict the consequences of various actions involving wildlife or fish habitat.

This publication represents the efforts of this group of professionals, primarily wildlife and fisheries biologists but also foresters, plant ecologists, hydrologists, and others, to pull together and place in rational order, the information a land manager needs to intelligently evaluate the impacts land use decisions will have on wildlife and fish resources. The land manager thus becomes more directly accountable for the decisions that are made.

Approximately 70 percent of the funds to support the project came from the U.S. Department of Argiculture, Forest Service, and 20 percent from the U.S. Department of the Interior, Bureau of Land Management. The remainder was provided by the U.S. Department of the Interior, Fish and Wildlife Service; the Oregon Department of Fish and Wildlife; and the Washington Department of Game. In addition, the Washington Department of Game provided office space and support services for the technical editor and his editorial clerk, and the Oregon Department of Fish and Wildlife funded technicians to aid in compiling the massive amount of data presented in the appendices. The Olympic National Forest provided use of their word processing equipment; furnished supplies; and aided with contracting, timekeeping, and copying and distributing the volumes of material.

More than 70 individuals (acknowledged elsewhere) contributed directly in the preparation of manuscripts and appendices. Contributing personnel came from the agencies listed above plus the U.S. Department of Agriculture, Soil Conservation Service; Washington Department of Fisheries; and Oregon State University. From the private sector, personnel from the Weyerhaeuser Company and the Northwest Timber Association participated. Many others not identified assisted with review comments, information, and advice.

Jack Ward Thomas and Chris Maser contributed generously of their time and made many helpful suggestions. The Information Services Staff of the Pacific Northwest Forest and Range Experiment Station, notably Betty Bell, were especially helpful in aiding the technical editor in editing procedures, format, and so forth. Charles Meslow, William Cowan, Harry Wagner, and Larry Bright served as an editorial panel, reviewing all the manuscripts. Alan Curtis assisted the technical editor throughout the project and performed many time consuming tasks such as selecting items for the glossary and obtaining definitions for them, and obtaining scientific names for plant species mentioned.

Barbara Braly typed most of the manuscripts and several hundred pages of narrative material about individual wildlife species that were prepared in conjunction with the project. She was also a valuable addition to the editorial team.

Getting a document of this kind ready for publication requires a great deal of expertise not possessed by the technical editor. Gail Saunders of the U.S. Department of Argiculture, Forest Service, Pacific Northwest Region's Information Office accepted responsibility for specifying type, administering contracts for typesetting and layout, and preparing much of the artwork. Her efforts have materially improved the quality of the handbook.

The values or contributions of this handbook are a direct reflection of the ideas and efforts of the many people who authored or otherwise contributed to it. The success of this work, however, rests in the hands of its users.

E. READE BROWN
Technical Editor

Foreword

The National Environmental Policy Act of 1969, the Forest and Rangelands Renewable Resources Planning Act of 1974, the National Forest Management Act of 1976, and the Federal Land Policy and Management Act of 1976 combined to thrust Federal forest managers into a new era. That new era was characterized by the requirements of these laws for Federal forest land managers to do a more comprehensive job of dealing with multiple-use management. An important component of these new legal requirements was wildlife and wildlife habitat. Not only were there more stringent requirements to address wildlife issues, but the existing understanding and definition of wildlife was changed. No longer was wildlife to be thought of only as game species. All species were to be considered in planning and management.

When compliance with these mandates was less than adequate, even when that lack of compliance was based on inadequate knowledge or tools, the courts reminded managers that compliance was required. By the mid-1970's teams in the Southwest and the "east side" of Oregon and Washington were developing mechanisms whereby these burgeoning needs could be addressed. In 1979, David Patton's Forest Service (U.S. Department of Argiculture) research unit in Tempe, Arizona, came out with "Run Wild," a computerized information storage and retrieval system that provided a habitat-oriented data base for Arizona and New Mexico. The "Blue Mountain Boys," an informal coalition of some 60 technical experts of various disciplines from several Federal and State agencies and universities that collaborated between 1973 and 1976, devised a system of evaluating wildlife habitats in managed forests that became available in draft form in 1976. These original efforts spread rapidly via photocopies and word of mouth. The effort was recognized as having real potential in 1977, and "Wildlife Habitats in Managed Forests – the Blue Mountains of Oregon and Washington" was published in 1979. This was quickly followed by "California Wildlife and Their Habitats: Western Sierra Nevada" in 1980; "Wildlife Habitats in Managed Rangelands – the Great Basin of Southeastern Oregon" in 1983; and many others that were less formally published.

In the meantime, the USDA Forest Service established a working group at Fort Collins, Colorado, under the direction of Hal Salwasser to stimulate and guide such efforts. This Fish and Wildlife Habitat Relationships Program was further tangible recognition that there was a commitment to satisfy the requirements of the law so far as adequate consideration of wildlife in land-use planning and management was concerned.

This handbook is an additional fulfillment of that commitment. It indicates what can be accomplished by dedicated natural resource professionals when they "stick their necks out" and make their best effort to combine existing knowledge and ecological theory into working hypotheses about the interaction of wildlife and the managed forest.

This handbook will quickly become outdated as it has, to some extent, outdated its predecessors. Good! Wildlife biologists are making progress in dealing with wildlife in managed forests and much more rapidly than wildlife biologists dreamed possible in the mid-1970's.

Yet it behooves those involved in management of forest lands to recognize that we stand at the beginning of the process of developing an understanding of how wildlife relates to habitat, not at

the end. Wildlife biologists have made a good start—but it's only a start. The hypotheses used in these models must be tested and modified, the understanding of how wildlife relates to habitat must be strengthened, and the appreciation of community ecology must be improved. But, to paraphrase Martin Luther King, Jr.: We are not where we want to be; we aren't where we are going to be; but, thank goodness, we aren't where we were!

Managers now have the tools to do a better job of considering wildlife within the fabric of the managed forest—this handbook clearly demonstrates that. They have the skill. A large question remains. Do forest managers have the will to do a better job for wildlife in the managed forest?

Without that will, this is likely to be just another book among many others that reside in pristine condition in neat rows on a thousand shelves. With such will it can be a powerful and effective tool; a catalyst; and a dog-eared, written-in, smudged, used companion to forest management professionals in western Oregon and Washington and elsewhere. Sometimes, in dark moments, I fear that the will is lacking. But, more strongly, I want to have hope and to believe that such will exists. Time will tell.

JACK WARD THOMAS
Chief Research Wildlife Biologist
USDA Forest Service
Pacific Northwest Forest
and Range Experiment Station
La Grande, Oregon

Table of Contents

Chapter Narratives

1

Introduction

E. Reade Brown
Alan B. Curtis

Table of Contents

Introduction

Human activities to modify living space and to produce food, fiber, fuel, and other necessities have significantly altered wildlife and fish habitat throughout much of the world. Forested regions are one of the last remaining natural habitats for fish and wildlife but most of these can no longer be considered "wild" (fig. 1). They are now managed for multiple use benefits including timber production (Thomas 1979a). Remaining stands of virgin timber are rapidly being harvested and converted to young tree stands that are intensively managed to produce maximum yields of wood fiber. Even areas not managed for timber production may be altered through livestock grazing programs, recreational use, or fire protection. Management activities applied to these forested lands alter fish and wildlife habitat significantly and frequently.

Traditionally, management of fish and wildlife species has been the prerogative of state wildlife agencies, while management of their habitat has been the responsibility of the landowner or the administering agency. Thus close cooperation is required in establishing and achieving fish and wildlife management objectives.

Before land managers can make intelligent decisions concerning the effect of forest management activities on fish and wildlife resources they must have information concerning the habitat requirements of various wildlife species and how this habitat will be altered by forest management. Although much information is available, it often is fragmented and not readily available to land managers. The purpose of this handbook, encompasing two volumes, is to summarize pertinent information concerning fish and wildlife habitats in the managed forest of western Oregon and Washington, to show how these habitats are altered by forest management acitivities, and to discuss some of the alternatives to benefit fish and wildlife that are available to land managers when making decisions concerning the management of timber resources. Narrative discussions are included in Volume One, while data on which the narratives are based is shown in the appendices in Volume Two.

Figure 1.—The forest lands of western Oregon and Washington are some of the most productive in the world.

The Problem

Wood fiber and wildlife are both products of the same land base. Decisions concerning the management or manipulation of forest tree cover are also decisions affecting fish and wildlife and their habitat. In the past, consideration of wildlife habitat requirements has seldom been fully integrated into the decision making process. When wildlife was thought of, it was usually only in terms of those species that might cause an economic loss to the landowner (fig. 2).

Figure 2.—The snowshoe hare feeds on Douglas-fir seedlings and where abundant, may cause problems for the landowner.

At the same time, wildlife managers were concerned with those species that were of economic importance to their constituency, primarily game birds, fish, and mammals. Since they seldom had control over the habitat on which this wildlife was produced, wildlife managers tended to concentrate their attention on the fish and wildlife species rather than on their habitat.

In recent years both forest management and wildlife management have undergone extensive changes. Forestry is moving from an age of extensive exploitation of a fixed inventory to intensive management of a renewable resource (Coleman 1980). Wildlife management has changed from concentration on a few economically important or highly visible wildlife species to attention being focused on the broad spectrum of fish and wildlife species, both game and nongame (Silovsky and Pinto 1974) (fig. 3). Public attitudes towards both forestry and wildlife management also have changed (Bunnell 1976, Clawson 1975). Today the public has a greater awareness of natural resources and "the days are passing when resource abuses, whether active or passive, will be tolerated" (Giles 1962).

Figure 3.—Wildlife management has changed in recent years to focus attention on all wildlife species, not just those of economic importance or high visibility.

Wagner (1977) pointed out that too often resource-management decisions are made by a single agency, with a single resource and a single value of that resource in mind. The forester concentrates on the best way to harvest Douglas-fir to ensure regeneration of the stand and minimize harvest costs while the wildlife biologist, with a similarly narrow focus on population numbers, often has failed to appreciate the complex habitat and ecosystem relationships which the species need to survive.

Both timber and wildlife are products of the forest and programs to produce each have a common base, the land. Harsay (1978) states: "Land is our greatest resource. If well managed, it is capable of providing a multitude of benefits in the long run. Knowledge and understanding of complex relationships are the two indispensable prerequisites of good land management."

The growing public concern for the management of all natural resources has manifested itself through increasing constraints placed on the resource manager. Many of these constraints relate to wildlife and the effect management of both public and private lands have on wildlife habitat. For the public land manager numerous laws, regulations, and agency policies mandate consideration for wildlife. For example, the USDA (1980) Policy on Fish and Wildlife, states: "Fish and wildlife habitats on National Forest System lands will be managed to maintain viable populations of all existing native vertebrate species and to maintain and improve habitats of management indicator species. All land management plans for National Forest and/or FS Regions will state the desired future condition of fish and wildlife, where possible, in terms of both animal population trends and of amount and quality of habitat." An excellent discussion of the laws and regulations governing the management of federal lands is provided by McGuire (1981).

Although state and private lands do not receive as much management guidance as federal lands, they are subject to direction from state laws as well as pressure from the general public. The Washington Forest Practices Act of 1974 as amended, states: ". . . that it is in the public interest for public and private commercial forest lands to be managed consistent with sound policies of natural resource protection; that coincident with maintenance of a viable forest products industry, it is important to afford protection to forest soils, fisheries, wildlife, water quantity and quality, air quality, recreation, and scenic beauty." The Oregon Forest Practices Act states: "Recognizing that the forest makes a vital contribution to Oregon by providing jobs, products, tax base and other social and economic benefits, by helping to maintain forest tree species, soil, air and water resources and by providing a habitat for wildlife and aquatic life, it is hereby declared to be the public policy of the State of Oregon to encourage forest practices that maintain and enhance such benefits and such resources, and that recognize varying forest conditions."

Whether public or private, land managers can no longer base their decisions solely on maximizing dollars returned for dollars spent. Today's natural resource manager must operate in a decision-making environment that requires dealing with long-run considerations of multifaceted goals, conflict among agency clientele, and ill-defined or non-existent norms of social welfare (Alston and Freeman 1975). Many of these goals appear to conflict and much of the criticism directed at the land manager today stems from a lack of, or a perceived lack of, consideration for fish and wildlife resources (fig. 4).

Figure 4.—Perpetuation of snags for cavity using wildlife species in the intensively managed forest presents a challenge to the forest-land manager.

Towell (1978) has proposed a six part "wildlife ethic" for foresters ". . . that could go a long way toward resolving major forestry-wildlife conflicts." The six parts are:

> 1) make fish and wildlife equal partners with trees in forest-land management plans; 2) initiate and accelerate research on silvicultural methods that combine timber and wildlife management; 3) diversify the forest stand as much as possible; 4) make greater use of fire to the advantage of both trees and wildlife; 5) maintain enough flexibility in silvicultural systems to provide for unusual wildlife situations; 6) exercise extreme care in logging operations on areas of high value to wildlife or other resources and uses.

Before land managers can make intelligent and defensible choices among increasingly complicated management alternatives, they must have the information they need to evaluate the environmental consequences of the various alternatives. It is one of the roles of fish and wildlife biologists to supply this information concerning wildlife resources.

Research on wildlife populations often is difficult at best, and in many cases research findings may be incomplete or lacking (fig. 5). In these cases biologists will need to apply their "best judgement" to the situation. To fail to do so is to shirk their responsibilities. Decisions concerning management of timber resources will be made, with or without fish and wildlife input. Although biologists do not have all the answers, far more information is currently available than is being used to resolve problems.

Figure 5.—Even trees do not always develop in patterns that we would expect. Wildlife population dynamics are far less predictable.

A Basic Assumption

A basic assumption that must be made in the highly productive forest areas of western Oregon and Washington is that most wildlife habitat management will be carried out in coordination with timber management. Timber production on the majority of lands has been and will continue to be the prime determinant of land use. Large-scale alterations of wildlife habitat occur daily but only as the result of timber management activities. The statement by Giles (1962) remains true today: "The time has come to face up to the fact that the harvest of wood, a forester's function, has greater influence on game (wildlife) than any active technique available to the wildlifer. In one sale a forester can . . . influence more cover over a longer time than a game (wildlife) manager with today's funds can create . . . in a decade. The wildlifer, realizing the potentials of the wood harvest, must not only increase the effectiveness of present practices, but must provide guidance for foresters so their efforts will not so strongly negate his efforts and can be made to complement them."

Thomas (1979a) added further emphasis: "Timber management is wildlife management. The degree to which it is good wildlife management depends on how well the wildlife biologist can explain the relationship of wildlife to habitat to achieve wildlife goals" (fig. 6).

In western Oregon and Washington approximately 500,000 acres annually are affected by timber harvesting operations (Department of Natural Resources 1981, MacLean 1980). Additional large acreages are affected by other silvicultural practices such as thinning, fertilization, competition control, and by road building. All of these practices affect habitat for a great many fish and wildlife species. Whether effects are positive or negative depends on the practice and the wildlife species involved.

Large-scale wildlife goals must be accomplished through timber management

because

timber management:

- affects many acres
- is well financed
- dramatically affects wildlife habitat
- has great impact on wildlife populations

while

wildlife habitat management:

- affects few acres
- has little financing
- has limited influence on wildlife habitat overall
- has limited present impact on wildlife populations

Figure 6.—Large-scale wildlife habitat management must be accomplished through timber management (adapted from Thomas 1979a, p. 13).

Management Systems

Timber

Timber management systems, through the changes they create in vegetative structure and successional patterns, cause tremendous changes to fish and wildlife habitats. The type of habitat created is largely determined by the timber management system.

There are two basic timber management systems used in the Northwest, even-aged and uneven-aged management, each fulfilling a different set of objectives for the forester. In the area west of the Cascade Range in Oregon and Washington, by far the most common approach has been some form of even-aged management (Scott 1980).

Even-aged Management

Timber harvesting under even-aged management systems can take one of three forms: clearcutting, shelterwood, or seed-tree method. The clearcutting method removes all trees from the cutting unit leaving only slash and ground vegetation (fig. 7). Slash frequently is burned to prepare the site for forest regeneration. Regeneration can be by either natural or, more commonly, artificial means. The seed-tree method involves leaving scattered individual or small clumps of trees at the time the remainder of the stand is harvested thus providing a seed source for natural regeneration. With the shelterwood method the original stand is gradually removed in a series of partial cuts over a fairly short period of time. It could be accomplished with as little as two entries into the stand but usually takes three or more. The first entry opens up the stand and creates a seed bed for natural regeneration. The second entry further opens the stand but leaves enough trees, not only for a seed source, but to modify the micro-climate for the new seedlings. The final entry removes the remainder of the older stand at a time when the new reproduction no longer needs shelter and can fully occupy the growing space (Hawley 1946).

Figure 7.—The clearcut method of timber harvest can result in a forest mosaic of stand conditions with a high degree of between-stand diversity.

Figure 8.—Even-aged management using the clearcut harvest method and regeneration with hand-planted nursery stock produces stands with very low within-stand diversity.

All of these harvesting systems result in essentially even-aged stands with the least variation in age occurring on clearcuts with artificial regeneration. In this case variation in tree age is usually less than 10 years and often virtually zero where the area is hand planted with nursery stock, (fig. 8). Clearcutting is the most commonly used method of tree harvest in western Oregon and Washington.

The seed-tree method is seldom used but the shelterwood method is gaining in popularity (Scott 1980, Hoyer 1980). Both of these methods produce even-aged stands but with more variation in the age of reproduction, which may vary up to as much as 20 years. Use of artificial regeneration techniques rather than relying on natural seeding can substantially reduce this variation.

Even-aged management produces forest tree stands having low within-stand structural diversity but with high between-stand diversity if cutting units are dispersed over the landscape. Clearcutting methods create the greatest between-stand diversity ranging from the grass-forb stand condition which provides habitat for many wildlife species such as horned larks and long-tailed voles that prefer open environments, to mature timber, that provides hiding and thermal cover for deer and elk and nesting and feeding trees for those species such as the pileated woodpecker that find optimum habitat in mature forests. The shelterwood method provides more within-stand structural diversity at the beginning of the rotation because of the retention of overstory trees, but the early seral stages or stand conditions produced by clearcutting may be severely shortened or bypassed entirely. This method would favor those wildlife species requiring greater within stand structural diversity but could seriously reduce species requiring more open habitats.

With even-aged management and small dispersed cutting units, a high diversity of wildlife habitats is created. Successional patterns lead to varying stand conditions with a great many edges that provide a variety of habitat niches for wildlife, even though there is relatively low structural diversity within the stands. Wildlife habitat diversity would probably be the highest if two or more of the even-aged harvest methods were used in the same drainage basin.

Another important element of even-aged management systems is the rotation age at which stands are harvested. There is a great deal of variation in rotation lengths depending on the goals and objectives of the land managing agency. Ecological, biological, sociological, and economic factors all play a role in determining when a timber crop is harvested. In general, privately-owned industrial forest lands tend to be managed on rotations of 40 to 60 years. Federally-owned forest lands with more sociological and ecological constraints tend to be managed on longer rotations, usually 60 to 100 years (Scott 1980).

In intensively managed forest stands any of these rotations will eliminate those stand conditions that have the greatest within-stand structural diversity, old-growth and the older seral stages of the mature forest. As Harris et al. (1982) point out: "Very early or very late successional stages provide primary habitat for twice as many species as the middle-aged stands. . . . Unfortunately, the two mid-successional stages of least value to wildlife dominate about 60 percent of the standard rotation time of 80 years."

Uneven-aged Management

Uneven-aged stands are developed by selectively harvesting individual trees or small groups of trees at frequent intervals. The system is best suited to those areas where the dominant or preferred tree species are shade-tolerant since reproduction must occur under the canopy of older trees in the stand. Shade-intolerant species tend to disappear from such stands (Franklin 1977).

The system produces a stand with a great deal of variation in the age of the tree species, from new seedlings to mature trees. This creates within-stand structural diversity that will provide preferred habitat for some wildlife species but lacks the distinct successional stages that are produced with even-aged management. Large blocks of continuous forest cover dominated by mature trees are created. The general effect is to reduce the diversity of plants and animals in the forest (Thomas 1979a).

This system is used only sparingly in western Oregon and Washington with its greatest application in the mixed conifer stands of southwest Oregon (Scott 1980). In western Washington, the Department of Natural Resources (1981) reported that of 174,196 acres logged in 1981, only 29,056 acres (16.7 percent) were partial cut, not including commercial thinning.

Roads

Roads are another component of timber management systems that have a significant impact on fish and wildlife and their habitat. Under intensive forest management each square mile of forest land will contain approximately six miles of road (Larsen 1974). Roads remove habitat, increase sedimentation in streams, affect wildlife distribution and movement patterns, and increase the potential for outside disturbance factors.

Silviculture

Each timber management system and silvicultural practice used will have different effects on a specific wildlife species or related group of species. No one system is all good or all bad in its effects on wildlife. Each system must be evaluated for the area on which it will be applied and in light of wildlife management goals for that area. To fulfill wildlife management goals the timber management system and silvicultural practices should produce stands having the desired structure, size and shape, and relationship to other stands.

Hartman (1976) points out that in many cases where a standing forest provides a significant flow of valuable services, management decisions made on timber values alone may be incorrect. He states: "The basic conclusion of this analysis is that the presence of recreational or other services provided by a standing forest may well have a very important impact on when or whether a forest should be harvested."

Taking into consideration all of the multiple-use values of a forest stand can significantly alter decisions concerning the timing and distribution of forest practices and the silvicultural management systems used (Calish et al. 1978, Crawford et al. 1981, Gonsior and Ullrich 1980, Walter 1977). Often the two major management systems can be used to complement one another. For example an uneven-aged system could be used to protect the integrity of riparian zones while an even-aged system is used to create a diversity of stand conditions and wildlife habitats in the surrounding area. "Flexibility in the use of silvicultural systems can be a key to meeting a range of wildlife goals" (Thomas 1979a).

Forest Wildlife

Habitat is the key to wildlife abundance. Depending on wildlife goals, managers should aim to provide an "even flow" of diversified habitats. Past actions control present habitat productivity just as present actions will control future habitat quality and quantity. A continuing variety of habitats must be provided if a wide range of wildlife species is to be maintained. Stable habitat conditions greatly contribute to stable wildlife populations.

The U.S. Department of Agriculture policy (USDA 1980) identifies two major management philosophies for wildlife. These are: 1) indicator or featured species managment and, 2) management for species richness or ecosystem management (fig. 9).

Production goal	Featured species management	Management for species richness
Objective	Produce selected species in desired numbers in designated locations. Production of selected species is of prime importance.	Insure that all resident species exist in viable numbers. All species are important.
Process	Manipulate vegetation so that limiting factors are made less limiting.	Manipulate vegetation so that characteristic stages of each plant community are represented in the vegetative mosaic.

Figure 9.—Production goals in wildlife management (from Thomas 1979a, p. 16).

Indicator or Featured Species

This is the most common approach and usually is directed toward species of economic importance such as game birds, big game, fur bearers, or those that cause economic problems such as coyotes or mountain beaver. Also falling into this category would be the threatened or endangered species and highly visible species that generate public attention such as the osprey, sandhill crane, or mountain lion (Besadny 1979).

Zeedyk and Hazel (1974) define the featured-species concept as: ". . . an approach to habitat management whereby one wildlife species is selected for emphasis on a unit of land, and then its requirements are used to guide optimum coordination of habitat management with timber management on that unit." Silvicultural practices are adopted that will create the most desired habitat for the featured species commensurate with timber management objectives. Thus a sustained yield of both wildlife and timber can be provided although it must be recognized that tradeoffs will be required and seldom are either the wildlife or the timber resource maximized.

If the indicator or featured species selected has habitat requirements similar to those of a number of other species, they also will prosper. For example, if pileated woodpeckers were selected and their habitat requirements provided, many other cavity-using species would benefit.

Species Richness or Ecosystem Management

Ecosystem management for species richness is a newer and more complicated approach. This requires that management programs be directed toward aquatic or terrestrial plant communities which are important to all existing wildlife species known to utilize that particular ecosystem. Siderits and Radtke (1977) put it this way: "A wildlife plan or program then becomes the establishment of the desirable mixture of various components that will provide the greatest diversity through time and space on a sustained basis. A management plan geared to provide this diversity would have as its goal not a given number of animals of any one species, but a given acreage of quality environment that would support a variety of species in different densities, dependent upon the inherent capability of the area being managed."

To meet this goal a range of seral stages or stand conditions is needed for each plant community and the area with these conditions should be of a size and shape that will provide habitat requirements for the full assortment of native wildlife species (fig. 10). This interspersion of vegetative types, ages, and habitats can best be achieved through forest management but requires a high degree of coordination between forest and wildlife managers (Siderits and Radtke 1977). Managers must look at a broad spectrum of plant communities and stand conditions. Such planning must be directed at the forest or district level, not at individual timber stands.

Figure 10.—Ecosystem management for wildlife species richness would provide a diversity of habitats meeting the needs of many species.

Both the featured species and the ecosystem management approaches fulfill specific management objectives for different species. A featured species approach directed at management of a species like black-tailed deer will probably not fulfill the policy for "maintaining viable populations of all existing vertebrate species" (USDA 1980). At the same time an ecosystem management program providing a diversity of habitats will be pressed to fulfill the very specialized habitat requirements of a species like the spotted owl. The two systems can be used together, however, with one complementing the other (Thomas 1979a).

The Setting

The setting for this handbook includes those portions of Oregon and Washington that are west of the summit of the Cascade Mountain range. Although the data base presented here has been developed specifically for application in western Oregon and Washington, most of the information would apply to northwestern California and the coastal areas of southwestern British Columbia.

The area covered is vast and in order to maintain focus on managed forest lands no data are presented concerning wildlife habitats in urban settings, on agricultural lands, or alpine areas above the limits of commercial forest land. Much of the habitat data presented for managed forests will apply in National Parks and Wilderness Areas but management of these areas is not addressed.

Geomorphology

The region is dominated by two mountain provinces, the Coast Ranges, and the Cascade Range. The Coast Ranges are flanked by the Olympic Mountains on the north and the Klamath Mountains on the south. The two mountain provinces are generally separated by the Puget-Willamette Lowland province (fig. 11). While there are similarities in habitat in each province, there are also differences in origins and characteristics that influence responses to land use activities.

The Cascade Range forms a natural divide between eastern and western Oregon and Washington. Areas to the east of the range experience a rain-shadow effect while the climate to the west is dominated by the Pacific Ocean. Consequently more abundant vegetation and more diverse aquatic systems are found west of the summit. The Cascade Range is breached only by the Columbia River between Oregon and Washington.

The Cascade Range is of Mesozoic origin, but the present configuration resulted from uplift and volcanism during the past 10 million years. During the Pleistocene period, glaciers covered most of the region. The western slopes show the effects of more recent geologic activity and are dominated by volcanism. Slopes and soils tend to be relatively stable and not highly erosive.

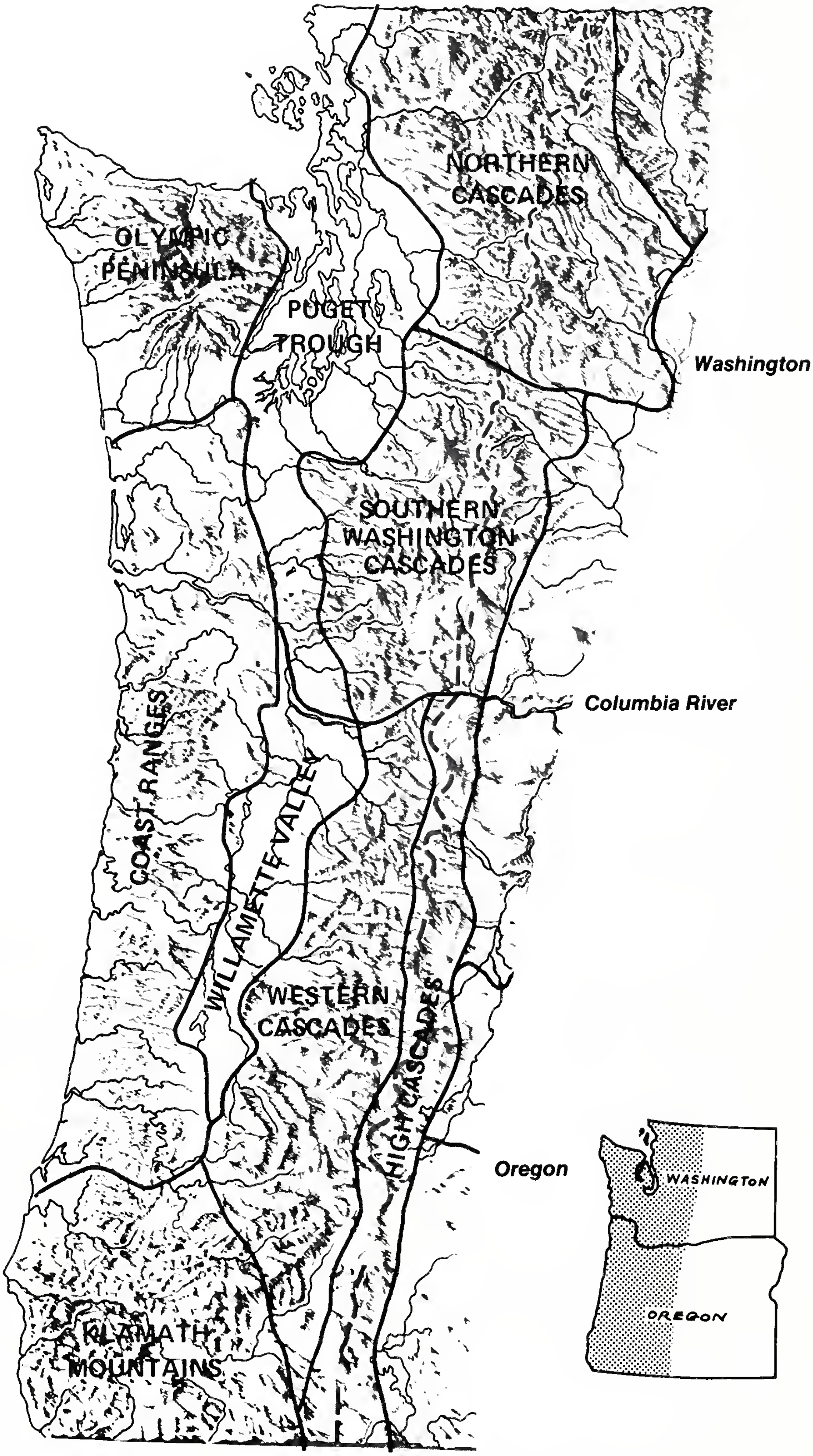


Figure 11.—Physiographic and geological provinces of western Oregon and Washington (adapted from Franklin and Dyrness 1973, p. 6).

The Coast Ranges are of more recent origin resulting from uplift during the late Tertiary period and are composed largely of sedimentary rock with some volcanic intrusions. These sedimentary materials are more erosive than the primarily igneous rock found in the Cascade Range (Snavely and Wagner 1963). Both surface erosion and mass erosion is more common in the Coast Ranges than in the Cascades.

Streams along the western face of the Coast Ranges flow directly into the Pacific Ocean, while streams from the eastern slopes drain to the Pacific via the Willamette, Cowlitz and Columbia Rivers. Many Coast Range streams in southern Oregon reach the sea via the Rogue and Umpqua Rivers which head in the Cascades and penetrate the Coast Ranges. In Washington, streams originating on the east side of the Olympic Mountains flow into Hood Canal while those originating in the Cascades flow into Puget Sound.

Running northward through the two states is the depression called the Willamette-Puget Lowland which separates the Coast Ranges from the Cascade Range. The southern portion of the depression is occupied by two major rivers, the Willamette and Cowlitz, while the northern part of the depression includes Puget Sound and Hood Canal.

Climate

Western Oregon and Washington have a maritime climate with mild wet winters and cool dry summers. Moisture laden clouds sweeping in from the Pacific Ocean and rising to pass over the Coast Ranges, Olympic Mountains and the Cascade Range deposit abundant precipitation on the area, 75 to 85 percent of which occurs between October 1 and March 31 (Franklin and Dyrness 1973). Precipitation at lower elevations occurs primarily as rain while at higher elevations snowfalls are heavy.

Physiography and latitude also play important roles in establishing climatic patterns. Mountain ranges along the coast create a rain shadow effect with much lower levels of precipitation in the Puget and Willamette lowlands. Precipitation patterns again increase with elevation along the west slope of the Cascade Range. Latitudinal effects result in cooler, moister weather patterns in northwestern Washington and warmer, drier patterns in southwestern Oregon.

Annual precipitation varies from more than 120 inches on the western slopes of the Coast Ranges and the Olympic Mountains, to lows of less than 25 inches in the rain shadow of the Olympics and some of the interior valleys of southwestern Oregon. Throughout most of the forested areas of western Oregon and Washington, however, annual precipitation averages 50 inches or more.

Mean January minimum temperatures for western Oregon and Washington coastal and lowland areas are 32 degrees Fahrenheit or above. Only the higher mountain areas of the Olympics and Cascades have mean January temperatures below 23 degrees Fahrenheit. July mean maximum temperatures for most of western Washington do not exceed 75 degrees Fahrenheit while those for western Oregon do not exceed 80 degrees Fahrenheit although some portions of southwestern Oregon have higher means (Franklin and Dyrness 1973).

Flora

The portion of Oregon and Washington west of the crest of the Cascade Range encompasses approximately 35 million acres of which 78.5 percent are forested (Basset and Oswald 1981a, 1981b, 1982; Gedney 1982). These forests are dominated by coniferous tree species, commonly called "softwoods" (Franklin and Dyrness 1973). Weather systems moving inland from the Pacific Ocean create moisture and temperature regimes that are ideally suited to the establishment and growth of coniferous tree species. Douglas-fir, western hemlock, western redcedar, Sitka spruce, Pacific silver fir and several other tree species indigenous to the region produce forests that "are unrivaled both in size and longevity of individual trees and in the accumulations of biomass of individual stands" (Waring and Franklin 1979) (fig. 12).

Originally, about the only areas of western Oregon and Washington not timbered were some prairies in the Puget Sound trough and the Willamette Valley and drier sites in southwest Oregon. The warmer drier climate of southwest Oregon also creates several plant communities unique to that area (Franklin and Dyrness 1973).

Figure 12.—Mature coniferous forest stands provide a stand structure that is attractive to many wildlife species.

Most of the forest tree species attain heights of 150 to 200 feet or more (Franklin and Dyrness 1973). Because of this, significant layering occurs in natural stands. These stands have an overstory tree canopy, a sub-canopy of trees, a shrub layer, and a ground vegetation layer. This type of structure provides a diversity of habitats for many wildlife species, particularly forest birds.

Fauna

Climatic factors, combined with terrain and vegetation, have created a diversity of wildlife habitats ranging from the rocky islands and sandy beaches of the coastline to snow-covered peaks in the Cascades. Many of the fish and wildlife species inhabiting these areas have evolved in conjunction with the coniferous forests of the region. Black-tailed deer and Roosevelt elk are widely distributed; the bays and estuaries seasonally host masses of waterfowl and shorebirds; the extensive system of streams, lakes, estuaries, and the ocean support a large and economically important fishery resource; while the forested hills and valleys furnish habitat for a large number of game and nongame wildlife species. Some 460 wildlife and 178 freshwater and selected marine fish species have been identified as using the lands and waters of western Oregon and Washington.

Forest Production

The land base in western Oregon and Washington is used predominantly for the production of wood products. Timber harvests from the area from 1973 to 1982 averaged 11 billion board feet per year with a peak of 14 billion in 1973, and a low of 8.3 billion in 1981 (table 1).

The Douglas-fir region has been a major timber producer since the early 1900's with western Washington producing an all time peak harvest of 8.24 billion board feet in 1929 and western Oregon producing a peak harvest of 10.4 billion board feet in 1952. The peak combined harvest for both states occurred in 1968 when 16.2 billion board feet were harvested (Wall 1972) (fig. 13). Except for the recession period starting in 1980, harvests from the region have consistently been above 10 billion board feet annually since the end of World War II (table 1) (Wall 1972), with peak harvests occurring in the late 1960's and early 1970's.

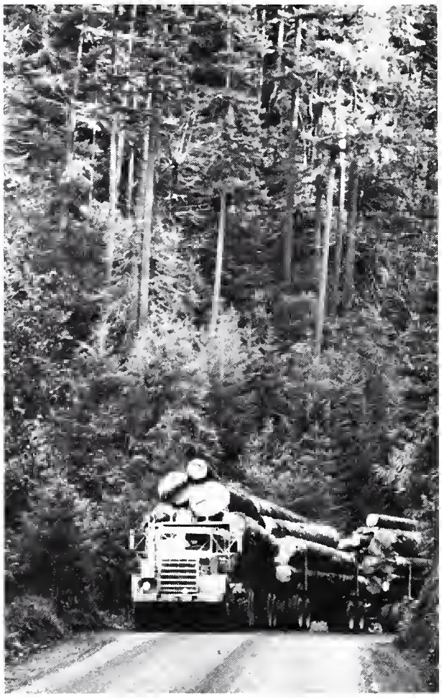


Figure 13.—The forest lands of western Oregon and Washington provide a significant portion of the nation's softwood timber production.

Table 1—Timber harvest statistics for western Oregon and Washington [1] (in thousands of board feet, Scribner log scale)

	Western Oregon			**Western Washington**			**Western OR & WA**
Year	Private[2]	Public[3]	Total	Private[2]	Public[3]	Total	Total
1973	3,050,196	4,366,852	7,417,048	4,342,954	2,247,574	6,590,528	14,007,576
1974	2,974,586	3,215,260	6,189,846	3,953,948	1,779,698	5,733,646	11,923,492
1975	3,065,647	2,301,515	5,367,162	3,723,657	1,448,501	5,172,158	10,539,320
1976	2,989,498	3,189,974	6,179,472	3,998,815	1,838,137	5,836,952	12,016,424
1977	3,063,233	3,002,206	6,065,439	3,635,863	1,785,899	5,421,762	11,487,201
1978	3,064,153	3,105,957	6,170,110	3,576,278	1,986,812	5,563,090	11,733,200
1979	2,773,817	3,339,084	6,112,901	3,621,764	2,219,745	5,841,509	11,954,410
1980	2,561,131	2,543,456	5,104,587	3,098,634	1,562,343	4,660,977	9,765,564
1981	2,225,969	2,081,892	4,307,861	2,899,310	1,057,867	3,957,177	8,265,038
1982	2,849,162	1,436,579	4,285,741	3,336,308	1,015,164	4,351,472	8,637,213
Average	2,861,739	2,858,278	5,720,017	3,618,753	1,694,174	5,312,927	11,032,944
Percent	50%	50%		68%	32%		

[1] Compiled by: Oregon State Department of Forestry, Washington State Department of Natural Resources, and the U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

[2] Includes harvest from forest industry and all other privately owned lands.

[3] Includes harvest from State and Federally owned lands.

Methods of transporting logs have changed dramatically over the years with varying effects on fish and wildlife habitat. Early day logging concentrated along water courses because the streams were the only means of moving logs to the mills. Both large and small streams were drastically altered by splash and roll dams designed to facilitate moving logs down stream (Van Syckle 1980). Stream channels were cleared and the sluicing that accompanied the movement of logs had serious impacts on salmonid spawning habitat. With the advent of the steam donkey and locomotive, timber harvesting activities were able to move uphill further from streams and into higher elevations. Although covering much broader areas, access was still restricted by the limitations of railroad grade construction. Today's logging is done almost exclusively by trucks with their greater freedom of movement, but this requires construction of many miles of logging road for each square mile of forest land.

Significant shifts in the concentration of timber harvesting activity in both Oregon and Washington have occurred over the years. In western Washington early timber harvesting efforts were concentrated around Grays Harbor, the Willapa Hills, and lowland areas around Puget Sound. Today the major production areas have shifted inland to higher elevations along the Cascade Range (Wall 1972).

Intensive timber harvesting in Oregon was slower developing than in Washington with early efforts concentrated in northwestern Oregon and lowland areas of the Willamette Valley. As virgin timber inventories were depleted in these areas major harvesting efforts moved south along the coast and to higher elevations in the Cascade Range (Wall 1972).

In the future it appears there will be an increasing emphasis on harvests from public lands. Although 68 percent of the Washington harvest and 50 percent of the Oregon harvest from the Douglas-fir region during the past 10 years was taken from private lands, 52 percent of the growing stock volume in Washington and 72 percent of the growing stock volume in Oregon is on public lands (fig. 14). A significant portion of the larger volumes of growing stock on public lands result from unharvested inventories of virgin timber while most of the virgin timber has been harvested from private lands (Department of Natural Resources 1975). This trend may be offset to some degree, however, by the higher growth potential of much of the privately held forest lands (fig. 14).

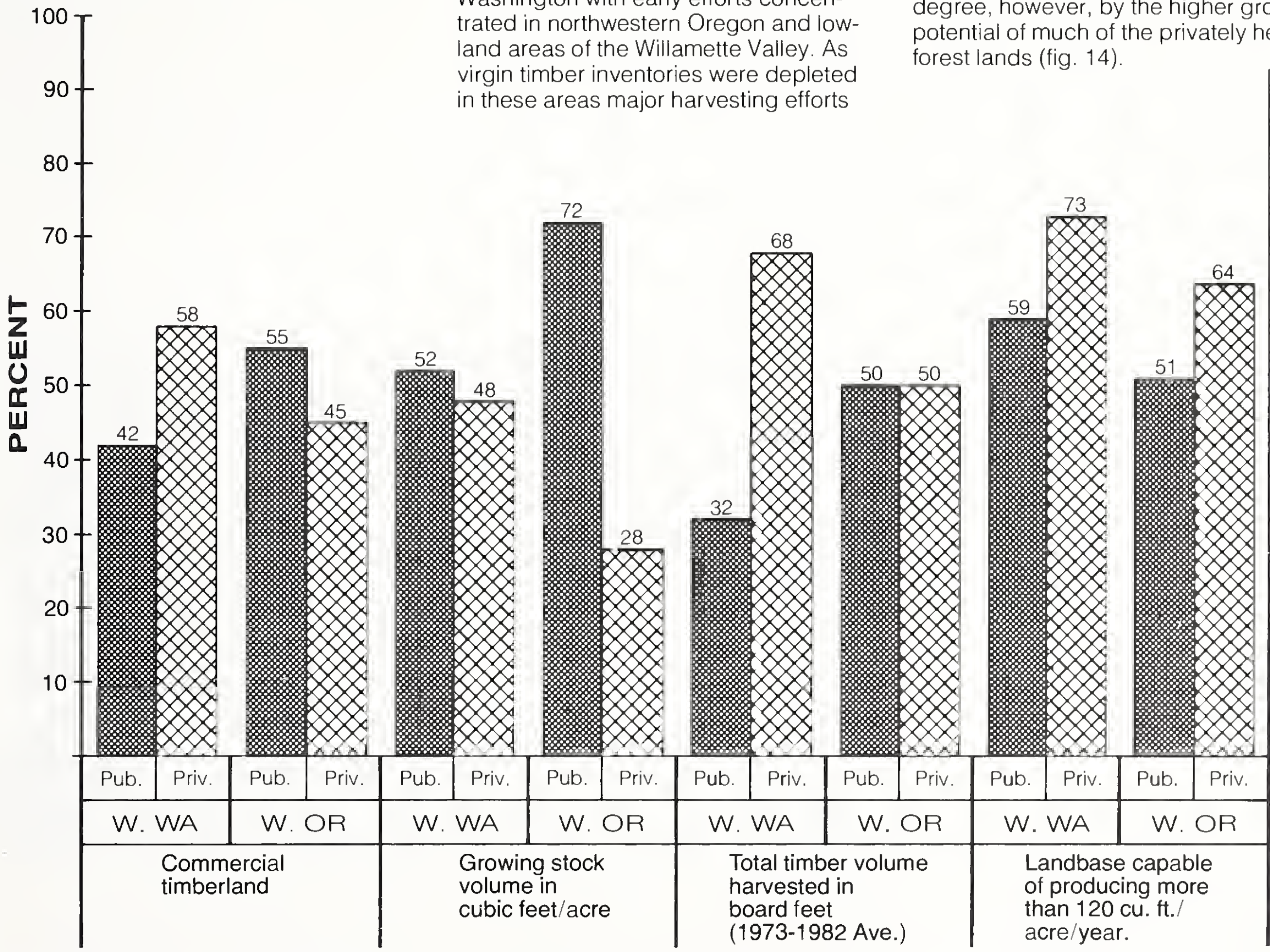


Figure 14.—Percent comparison of the timberland base, growing stock volume, volume of timber harvested, and landbase capable of producing more than 120 cu. ft. of wood acre/year for public and private land ownership in western Oregon and Washington (from Bassett and Oswald 1981a, 1981b, 1982; Gedney 1982).

The importance of timber production to the economy of the Pacific Northwest is emphasized by the fact that the average direct employment in forest products industries between 1973 and 1982 in Oregon and Washington was 147,300 people (Ruderman 1983). Larsen (1977) points out that in the State of Washington in 1975, direct and indirect employment as the result of forest products industries amounted to 181,000 or 17 percent of the state's labor force. Direct employment by forest products industries accounted for 26 percent of the state's total manufacturing work force.

Demand for forest products is expected to continue to increase in the future (Grantham 1974, Hair 1980, Ulrich 1981, U.S. General Accounting Office 1981) while at the same time the acreage available to produce those products can only decrease because of withdrawals for urban and suburban development; roads, powerlines, and reservoirs; and recreational and wilderness designations (Gedney 1981, Wall 1981).

Wildlife Associated Recreation

The same land base that is expected to produce wood products also is being used extensively for recreation. Recreational demands also are increasing, not only for hunting and fishing, but for opportunities to view wildlife and for protection of their habitat. The 1980 national survey of fishing, hunting, and wildlife associated recreation (U.S. Department of the Interior 1982) shows that 36 percent of the total population of Oregon over 6 years of age participates in fishing, hunting, or both activities. In the State of Washington the figure is 32 percent. Also 82 percent of Oregon and 77 percent of Washington residents participate in some form of non-consumptive wildlife associated recreational activity (table 2). Much of this recreational activity involves the entire family (fig. 15). Because the bulk of the human population in the two states resides west of the Cascade Range, pressure for recreational opportunity is intensified.

With demands increasing from all sides it is inevitable that resource conflicts will develop. To resolve these conflicts and produce an equitable distribution of products from the land base including wood products, wildlife, and recreation, is a major challenge facing the land manager. The following sections of this handbook provide the land manager with information that will aid him in making decisions concerning management of the forest and wildlife resources.

Table 2—Participation in wildlife associated recreation in Oregon and Washington (U.S. Department of the Interior 1982)

Activities by state residents		Number	Percent
	OREGON		
Total population		2,656,000	100%
State-resident sportsmen[1]			
16 years old and older		763,300	
6-15 years old		191,100	
	TOTAL	954,400	36%
Nonconsumptive participants total (6 years old and older)		2,170,400	82%
Primary[2]		1,077,900	41%
	WASHINGTON		
Total population		4,132,204	100%
State-resident sportsmen[1]			
16 years old and older		1,073,800	
6-15 years old		251,100	
	TOTAL	1,324.900	32%
Nonconsumptive participants total (6 years and older)		3,176,700	77%
Primary[2]		1,552,900	37%

1/ Includes both fishermen and hunters.

2/ Participated in a non-consumptive recreational activity where wildlife played a primary role in determining the type of activity..

Figure 15.—Many forms of wildlife associated recreational activity involves entire family groups.

The Following Chapters

The chapters are presented in the same sequence as those developed by Thomas (1979b) and are designed to present a logical progression of principles and ideas. The material is presented in two parts with the narrative portion of each chapter appearing in Part 1 and their attendant appendices appearing in Part 2.

Chapter 2 describes the plant communities and stand conditions used as the basis for discussing wildlife habitats throughout the handbook. The plant communities are categorized by the distinctiveness of wildlife habitats they create and may be different from those developed on a strictly ecological basis. Chapter 3 relates the habitat use by all terrestrial vertebrate wildlife species found in western Oregon and Washington to plant communities, stand conditions, and/or special and unique habitats. Each species finds optimum conditions in one or more habitats. With this information the land manager can determine which species will be affected by a silvicultural practice and predict how that practice will affect future wildlife habitats.

Chapters 4 through 9 discuss special and unique habitats. Thomas (1979a) describes special habitats as those that are: ". . . biological in nature, can be manipulated by the forest manager, and play a critical role in the lives of at least some species . . . Unique habitats are geomorphic in nature, usually cannot be manipulated to the advantage of wildlife, and are critical to certain species." The special habitats described include riparian zones (chapter 4), estuaries (chapter 5), edges (chapter 6), snags (chapter 7), and dead and down woody material (chapter 8). Riparian zones occupy a limited amount of space in the forest environment but receive a disproportionate amount of use by a great many wildlife species. Estuaries, although often far removed from the site of the actual forest manipulation, are the "end of the pipeline" and both vertebrate and invertebrate esturarine species can be significantly affected by forest management activities. Edges and their associated ecotones provide habitat for a great many wildlife species and also serve as an indicator of the diversity of habitats in a given area. Snags, an important component of habitat for many wildlife species, present a special challenge to the land manager if they are to remain a part of the intensively managed forests of the future. Although dead and down woody material provides habitat for certain wildlife species and is an important element in the health of forest ecosystems; dead and down material also is being drastically reduced in intensively managed forests. Unique habitats (chapter 9), including caves, cliffs, and talus, are used by a limited number of species that nonetheless add to the diversity of wildlife found in the forest. Although these habitats usually cannot be manipulated by the land manager, their microclimate may be adversely or beneficially affected by forest disturbance in the immediate area.

Chapters 10 through 13 discuss the habitat requirements of some featured species, or groups of species, that are of considerable importance in the managed forests of western Oregon and Washington. Chapter 10 discusses salmonids as a group since they are extremely important both economically and recreationally. Also the quality of their habitat is dependent to a large degree on forest management activities in the area. Chapter 11 discusses deer and elk habitat requirements because of their importance for sport hunting and because they are a highly visible species of concern to the public. Chapter 12 considers the spotted owl, a species classified as "threatened" by both the states of Oregon and Washington and federally listed on Appendix II of the Convention of International Trade in Endangered Species of Wild Fauna and Flora. This species and its habitat is of biological, political, and economic importance. Bald eagles (chapter 13) are listed as "threatened" in Oregon and Washington under the Endangered Species Act by the U.S. Fish and Wildlife Service and by the States of Oregon and Washington.

Chapter 14 discusses silvicultural options open to the land manager in meeting requirements for fish and wildlife while at the same time allowing a harvest of wood products. There often is more than one option available and with careful planning the manager can meet the objectives for both timber and wildlife.

While the earlier chapters predict the consequences of forest management activities on wildlife habitats, chapter 15 provides land managers with a system for predicting the consequences of wildlife habitat protection or mitigation on timber production. Under a multiple-use concept, all uses cannot be maximized simultaneously on a finite land and water base: inevitably, some uses must be held below potential. Land managers can make well-informed decisions only if they know all of the tradeoffs.

References Cited

Alston, R. M.; Freeman, D. M. The natural resources decision-maker as political and economic man: Toward a synthesis. J. Environmental Manage. 3: 167-183; 1975.

Bassett, P. M.; Oswald, D. D. Timber resource statistics for southwest Washington. Res. Bull. PNW-91. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981a; 24 p.

Bassett, P. M.; Oswald, D. D. Timber resource statistics for the Olympic Peninsula, Washington, Res. Bull. PNW-93. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981b; 31 p.

Bassett, P. M.; Oswald, D. D. Timber resource statistics for the Puget Sound area, Washington. Res. Bull. PNW-96. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1982. 31 p.

Besadny, C. D. State efforts to inventory wildlife habitat. 44th North Am. Wildl. and Nat. Resourc. Conf. Trans. Washington, DC: Wildlife Management Institute; 1979: 360-368.

Bunnell, F. L. The myth of the omniscient forester. For. Chron. 52(3): 150-152; 1976.

Calish, S.; Fight, R. D.; Teeguarden, D. E. How do nontimber values affect Douglas-fir rotations? J. For. 76(4): 217-221; 1978.

Clawson, M. Compatibilities and incompatibilities in multiple uses of forests. 40th North Am. Wildl. and Nat. Resource. Conf. Trans. Washington, D.C.: Wildlife Management Institute; 1975: 157-167.

Coleman, D. J. Forest management outputs; The issues. In: Manning, G. H., ed. Forest management outputs: Who needs them and why? 1979 October 1; Jasper Park Lodge, Alberta. Victoria, BC: Canadian Forestry Service, Pacific Forest Research Centre; 1980: 28-33.

Crawford, H. S.; Hooper, R. G.; Titterington, R. W. Songbird population response to silvicultural practices in central Appalachian hardwoods. J. Wildl. Manage. 45(3): 680-692; 1981.

Department of Natural Resources. Washington forest productivity study. Phase I Report. Olympia, WA: State of Washington, Department of Natural Resources; 1975. 156 p.

Department of Natural Resources. 1981 timber harvest report. Olympia, WA: State of Washington, Department of Natural Resources; 1981. 55 p.

Franklin, J. F. Effects of uneven-aged management on species composition. In: Uneven-aged silviculture and management in the Western United States. Proc. In-Service Workshop. 1976 October 19-21. Redding, CA. Washington, DC. U.S. Department of Agriculture, Forest Service, 1977: 64-70.

Franklin, J. F.; Dyrness, C. T. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-8.Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1973. 417 p.

Gedney, D. R. Change in area and ownership of private timberland in western Oregon between 1961-62 and 1973-76. Res. Bull. PNW-92. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981, 8 p.

Gedney, D. R. The timber resources of Western Oregon-highlights and statistics. Res. Bull. PNW-97. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1982. 84 p.

Giles, R. H., Jr. Timber-wildlife coordination concepts for large eastern forests. 27th North Am. Wildl. and Nat. Resourc. Conf. Trans. Washington, D.C.: Wildlife Management Institute; 1962: 402-412.

Gonsior, M. J.; Ullrich, J. R. Problems and opportunities in integrating and extrapolating research results. IN: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests. 1979 September 11-13; Missoula, MT. Ogden, UT: Gen. Tech. Rep. INT-90. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980: 497-514.

Grantham, J. B. Status of timber utilization on the Pacific Coast. Gen. Tech. Rep. PNW-29. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1974. 42 p.

Hair, D. Timber situation in the United States – 1952-2030. J. For. 78(11): 683-686; 1980.

Harris, L. D.; Maser, D.; McKee, A. Patterns of old growth harvest and implications for Cascades wildlife. 47th North Am. Wildl. and Nat. Resourc. Conf. Trans. Washington, DC: Wildlife Management Institute; 1982: 374-392.

Harsay, J. G. Efficiency, adaptability, and compatibility in multiple land use. Invironmental Manage. 2(3): 204-208; 1978.

Hartman, R. The harvesting decision when a standing forest has value. Economic Inquiry. 1976 March; 14: 52-58.

Hawley, R. C. The practice of silviculture. 5 ed. New York: John Wiley and Sons; 1946. 354 p.

Hoyer, G. E. Shelterwood regeneration opportunities in Washington State, defined by forest habitats. For. Land Manage. Cont. 203. Olympia, WA: State of Washington, Department of Natural Resources; 1980. 36 p.

Larsen, D. N. Washington forest productivity study. Phase II, Economic analysis. Olympia, WA: State of Washington, Department of Natural Resources; 1977. 38 p.

Larsen, J. S. Forest management practices and policies as related to wildlife. In: Black, H. C., ed. Wildlife and forest management in the Pacific Northwest. Proc. of a Symposium. 1973 September 11-12. Corvallis, OR. Oregon State University, School of Forestry; 1974: 193-196.

McGuire, J. R. The outlook for the national forests. XX. The Horace M. Albright Conservation Lectureship. Berkeley, CA: University of California, College of Natural Resources, Department of Forestry and Resource Management; 1981. 24 p.

MacLean, C. D. Opportunities for silvicultural treatment in western Oregon. Res. Bull. PNW-90. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 35 p.

Ruderman, F. K. Production, prices, employment and trade in northwest forest industries, first quarter 1983. Res. Bull. PNW-106. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1983. 54 p.

Scott, D.R.M. The Pacific Northwest region. In: Barrett J. W., ed. Regional silviculture of the United States. 2 ed. New York: John Wiley and Sons; 1980: 447-493.

Siderits, K.; Radtke, R. E. Enhancing forest wildlife habitat through diversity. 42nd North Am. Wildl. and Nat. Resourc. Conf. Trans. Washington, D.C.: Wildlife Management Institute; 1977: 425-434.

Silovsky, G. D.; Pinto, C. Forest wildlife inventories: Identification of conflicts and management needs. In: Black, H. C., ed. Wildlife and forest management in the Pacific Northwest. 1973 September 11-12. Corvallis, OR: Oregon State University, School of Forestry; 1974: 53-61.

Snavely, P.D.; Wagner, H. C. Tertiary geologic history of western Oregon and Washington. Rep. of Investigations 22, Olympia, WA: Department of Conservation, Division of Mines and Geology; 1963. 25 p.

Thomas, J. W. Introduction. In: Thomas, J. W., tech, ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agri. Handb. 553. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979a: 10-21.

Thomas, J. W., Tech. ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agri. Handb. 553. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979b. 512 p.

Towell, W. E. Needed: A wildlife ethic. Am. For. 1978 September: 9, 46-47.

Ulrich, A. H. U.S. timber production, trade, consumption, and price statistics 1950-80. Misc. Pub. 1408. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981. 81 p.

U.S. Department of Agriculture. Policy on fish and wildlife. Secretary's Memorandum No. 2019. Washington, DC: U.S. Department of Agriculture. Printed in: 45th North Am. Wildl. and Nat. Resourc. Conf. Trans. Washington, DC: Wildlife Management Institute; 1980: 60-66.

U.S. Department of the Interior. 1980 national survey of fishing, hunting, and wildlife-associated recreation. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service; U.S. Department of Commerce, Bureau of the Census; 1982. Oregon and Washington Supplements.

U.S. General Accounting Office. The nation's unused wood offers vast potential energy and product benefits. Report to the Congress of the United States EMD-81-6. Washington, DC: U.S. General Accounting Office, Comptroller General; 1981. 115 p.

Van Syckle, E. They tried to cut it all. Seattle, WA: Craftsman Press; 1980. 308 p.

Wagner, F. H. Species vs. ecosystem management: Concepts and practices. 42nd North Am. Wildl. and Nat. Resourc. Conf. Trans. Washington, DC: Wildlife Management Institute; 1977: 14-24.

Wall, B. R. Log production in Washington and Oregon – an historical perspective. Res. Bull. PNW-42. Portland, OR: U.S. Department of Agriculutre, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1972. 89 p.

Wall, B. R. Trends in commercial timberland area in the United States by state and ownership, 1952-77, with projections to 2030. Gen. Tech. Rep. WO-31. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 26 p.

Walter, G. R. Economics of multiple use forestry. J. Environmental Manage. 5: 345-356; 1977.

Waring, R. H.; Franklin, J. F. Evergreen coniferous forests of the Pacific Northwest. Science 204(4400): 1380-1386; 1979.

Zeedyk, W. D.; Hazel, R. B. The Southeastern featured species plan. In: Slusher J. P.; Hinckley, T. M. eds. Timber-wildlife management symposium. Mo. Acad. Sci. Occas. Pap. 3. Columbia, MO: Missouri Academy of Science; 1974: 58-62.

2

Plant Communities and Stand Conditions

Frederick C. Hall
Larry W. Brewer
Jerry F. Franklin
Richard L. Werner

Table of Contents

Introduction

The luxuriant vegetation of western Oregon and Washington is composed of an array of plant communities that provide habitats for a wide variety of terrestrial birds and animals. An understanding of how wildlife species relate to these plant communities and the stand condition within each community is basic to the development of a wildlife management program.

Wildlife habitats are determined by the interspersion of plant communities, by the structure of plant communities, and by the mix of species within a community. Although all of these are important to certain species of wildlife, most species respond more to structure of vegetation than to plant species making up a community (Thomas et al. 1979). For example, mature stands of the deciduous hardwood forest community provide habitats for a different group of wildlife species than does the temperate coniferous forest community, yet the grass-forb stand condition of both these communities may host the same wildlife species. Also, the shrub stand condition provides habitats for different wildlife species than do old-growth stand conditions in either community. It makes little difference to most wildlife whether the climax vegetation on a site consists of Sitka spruce, western hemlock, or western redcedar; but the stand condition of any of these tree species determines which wildlife species are present or absent.

Variation in plant species composition, stand structure, or both, that provide significantly different habitats for wildlife, served as the basis for developing the plant communities and stand conditions that are described in the following sections. Consequently, some combinations or separations of plant species may be different from those normally used by plant ecologists. Definitions used in developing these descriptions are as follows:

Plant community—a general kind of vegetation that at maturity is different from other kinds of vegetation for wildife habitat; it may be climax or it may be successional (red alder forest, for example). It usually includes several kinds of cover types; for example, deciduous hardwood forest includes Oregon white oak, California black oak and bigleaf maple. **Stand condition**—the size, density and species compostion of a plant community after disturbance and at various time intervals following the disturbance. The grass-forb stand condition, for example, follows clearcutting in which tree regeneration, such as Douglas-fir, is only 1 to 5 years old. The open sapling-pole stand condition may have many of the same plant species as the grass-forb stand condition, but it has trees larger than 1 inch in d.b.h. (diameter breast high) and less than 60 percent crown cover. Because size and density of a species are important components of stand condition, it may not be the same as a successional stage. **Stand structure**—the physiognomic makeup of a plant community (a hardwood tree overstory, a deciduous shrub layer, an herbaceous layer, few snags, and not much down woody material compared with a coniferous tree overstory, an evergreen shrub layer, a scant herbaceous layer, snags, and down woody material). Stand structure is further qualified by size of plant species composing the community. **Wetland**—sites where the soil is saturated with moisture most of the year resulting in unique plant communities. **Riparian zone**—the interface between plant communities and lakes, streams, ponds, reservoirs, or other bodies of water. At times wetlands are adjacent to water; other times, dryland plant communities occur in the riparian zone. **Interspersion**—the distribution of plant communities and stand conditions across the landscape; for example, clearcuts are often interspersed in old-growth forests.

In western Oregon and Washington, the mix of plant communities and stand conditions within communities varies considerably, often over relatively short distances (Maser et al. 1981). Much of this variation results from programs designed for the production or harvest of wood products. Forest managers influence the kinds of wildlife species and their abundance when they decide a forest stand will be significantly altered with treatment. Certain wildlife species will be adversely influenced, some benefited, and other species largely unaffected by timber management activities.

Silvicultural activities, including timber harvest, raise several questions. For example: what is the degree of impact on wildlife species for various treatments such as clearcutting, shelterwood cutting, precommercial thinning, or commercial thinning? How can adverse impacts be moderated or reduced by modified management activities and how long will these effects last? Which wildlife species are especially sensitive to changes in habitat and what habitat alterations are most critical to their well-being? Which wildlife species are threatened or endangered, and what stand treatments are most likely to enhance their habitats and what treatments are most likely to harm them?

Habitat, in most cases, is the prime determinant of wildlife welfare, and it is the basic topic of this book. Succeeding chapters will associate various wildlife species with the plant communities and stand conditions described here.

Plant Community Development

Physical Factors

The plant community found on a site, its structure and mix of plant species, is determined by the interaction of a broad matrix of factors. Different plant communities and variations within communities result from the history of disturbance, natural or caused by humans, along with differences in soils, moisture, temperature, nutrient availability, elevation, and aspect. Soils developed from sedimentary rock, for example, are rich in nutrients and produce different plant communities than sand dunes or volcanic ash deposits which tend to be low in nutrients. Riparian zones along a valley bottom where moisture is less limiting may produce a completely different plant community than will a nearby well-drained sloping hillside exposed to more intense sunlight.

Latitude is also an important factor in the development of a plant community. Including about the northern two-thirds of western Oregon and north through western Washington, coastal British Columbia, and southeast Alaska, the dominant vegetation is composed of similar tree species. Consequently, the array and mix of plant communities are similar. In southwest Oregon, however, a transition area occurs where these northern species start to mix with species more typical of the vegetation of northern California. This results in several plant communities unique to southwest Oregon along with a unique array of wildlife habitats and wildlife species.

Disturbance Factors

Distrubance may be the determining factor in the development of a plant community toward climax, but more often it affects the structure of that community. Disturbances may be either natural or caused by humans.

Wildfires started by lightning and trees blown down by severe windstorms have always been a part of the natural cycle affecting the structure of plant communities over broad acreages of forest land. Flooding, landslides, volcanic activity, and snow avalanches are other natural disturbances that have significant but more local impacts on plant community structure. Although such events may appear catastrophic at the time they occur, they too are a part of the natural cycle responsible for the plant communities that exist on otherwise undisturbed areas.

Human activities have added a new dimension that has altered plant structure over vast acreages. Timber harvest and silvicultural treatments after harvest have had the most widespread impact. Clearing of land for agriculture and for urban and suburban development and construction of utility and transportation networks have resulted in more severe disturbance, but over fewer acres.

Plant Communities as Wildlife Habitat

Each plant community and its stand conditions create distinct environmental conditions that fulfill the habitat requirements of certain wildlife species. By associating individual wildlife species with plant communities and stand conditions, the forest manager can translate standard forest inventories into information on wildlife habitats (Thomas et al. 1979).

Importance of Structure

The natural process by which one plant community or stand condition changes into another is known as succession. This regrowth of vegetation continues until the climax stage is reached unless it is modified by disturbance. As forest tree species develop and mature, whether they be deciduous or coniferous, the canopies close and herbs and shrubs that require direct sunlight start disappearing. As a stand condition changes, wildlife habitats change. For example, horned larks, Say's phoebes, and willow flycatchers—which may be common on an area with vegetation in the grass-forb or shrub stand condition—disappear from an area as the vegetation develops into the closed sapling-pole stand condition. At the same time, species such as the black-capped chickadee, varied thrush, and Townsend's warbler will begin to use the site because they prefer the structure of a mature forest community.

Although the composition of plant species may change on a site as the vegetation progresses through the various stand conditions, the dominant force is the changing structure of the forest tree species. In western Oregon and Washington, these changes occur rapidly. The structure of forest tree species becomes the major factor in determining wildlife habitats.

Basis for Plant Community Descriptions

The natural successional process creates a constantly changing mosaic of plant communities and stand conditions, particularly in areas that have been affected by some type of disturbance. Many of the criteria used as foundations for vegetation classification systems are

based on potential natural vegetation that would occur if fire or other disturbance were excluded (Mueller-Dombois and Ellenberg 1974). Some classifications cover broad areas and identify only major plant associations such as Küchler's (1964) description of "Potential Natural Plant Communities of the United States", whereas others give more detailed descriptions of plant communities in specific areas—Franklin and Dyrness (1973) "Natural Vegetation of Oregon and Washington" for example. Variation in composition of plant species is the basic characteristic for differentiation between plant communities in both systems.

For purposes of this publication, however, differentiation between plant communities was based on their having a plant species composition or structure that would provide significantly different wildlife habitat characteristics. Table 1 lists these plant communities and shows how they compare with the classification systems used by Küchler (1964) and Franklin and Dyrness (1973). Fourteen of the 116 forest and range ecosystems identified by Küchler (1964) for the United States occur in western Oregon and Washington (fig. 1).

The following sections provide a general discussion and show why each of the 15 plant communities and 6 stand conditions used in this publication were chosen and described as significant for wildlife habitat. For detailed descriptions of these plant communities and stand conditions, see appendices 5 and 6.

Table 1—Relationships between plant communities described in this publication and two other plant classification systems

Plant community designations used in this publication	Potential natural vegetation described by Küchler (1964)	Vegetation types described by Franklin and Dyrness (1973)
Herbaceous wetland	K49 Tule marshes	
Hardwood-shrubby wetland	K25 Alder-ash forest	Riparian vegetation
Coniferous wetland	K1 Spruce-cedar-hemlock K2 Cedar-hemlock-Douglas-fir	Sitka spruce zone Western hemlock zone
Grass-forb dry hillsides		Grasslands, interior valleys
Mountain shrubland and chaparral	K34 Montane chaparral	Sclerophyllous shrub
Deciduous hardwood	K26 Oregon oakwoods	Oregon white oak
Evergreen hardwood	K29 California mixed evergreen forest	
Red alder forest		Successional in Sitka spruce zone
Conifer hardwood forest	K29 California mixed evergreen forest	Mixed evergreen
Mixed coniferous forest	K5 Mixed conifer forest	Mixed conifer
Temperate coniferous forest	K1 Spruce-cedar-hemlock K2 Cedar-hemlock-Douglas-fir	Sitka spruce zone Western hemlock zone White fir zone
High temperate coniferous forest	K3 Silver fir-Douglas-fir K4 Fir-hemlock forest	Silver fir zone Mountain hemlock zone Red fir zone
Subalpine forest parks		Mountain hemlock zone
Lodgepole pine (Cascade Range)		Successional in mountain hemlock zone
Shore pine (Coast)		

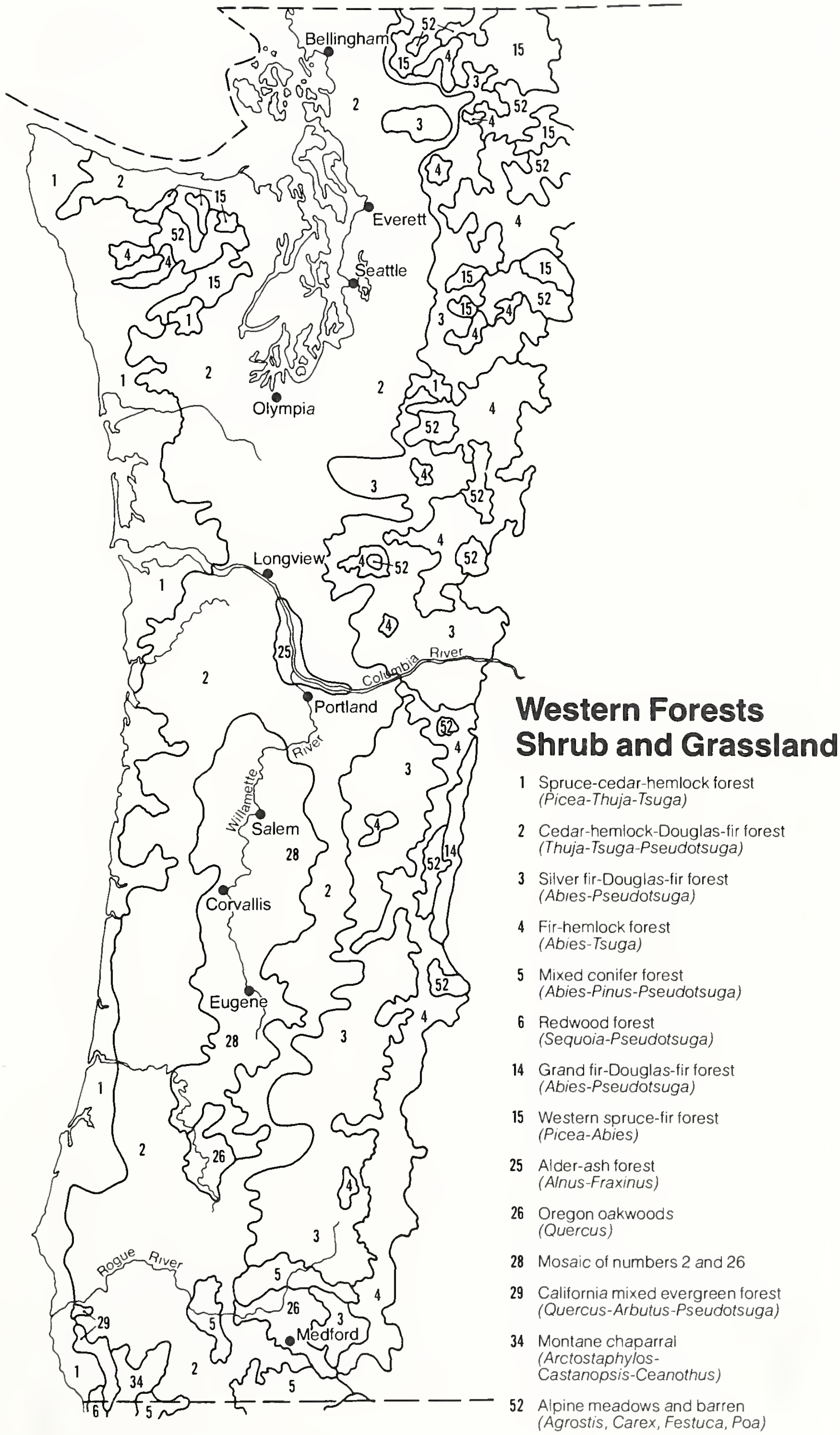


Figure 1.—Potential natural vegetation types for western Oregon and Washington (after Küchler 1964) (used with permission).

Plant Communities

The plant communities described are separated into 3 wetland types and 12 dryland types. The dryland types are further divided into nonforested and forested communities. Because these communities were chosen on the basis of differences in plant species composition or structure as composition and structure relate to wildlife habitat, some vegetation zones of concern to the forest-land manager have been combined. As an example, the Sitka spruce, western hemlock, and white fir zones of Franklin and Dyrness (1973), are all included in the temperate coniferous forest community. The silver fir, mountain hemlock, and red fir zones are all included in the high temperate coniferous forest community. Other communities such as subalpine forest parks or coastal shore pine may have little significance to the forest-land manager, but they provide wildlife habitat that is different from that of other forested communities. Some characteristics of the communities are summarized in figure 2.

Plant community designations	Plant diversity [1/]	Vegetation height	Canopy volume	Canopy closure	Structural diversity	Herbage production	Browse production	Animal diversity [1/]	Woody debris
Herbaceous wetland	●	●	●●	●●●●	●	●●●●●	●	●●	
Hardwood-shrubby wetland	●●●	●●●	●●●●	●●●●●	●●●	●●	●●●●	●●	●●
Coniferous wetland	●●●	●●●●●	●●●●●	●●●●●	●●	●	●●	●●	●●●●
Grass-forb dry hillsides	●	●	●	●●	●	●●●	●●	●●	
Mountain shrubland and chaparral	●●	●●	●	●●	●●	●●	●●●●●	●●	●
Deciduous hardwood	●●	●●●	●●●	●●●●	●●●	●●	●●●	●●●	●●
Evergreen hardwood	●●	●●●	●●●●	●●●●●	●●	●	●●	●	●●
Red alder forest	●●	●●●	●●●	●●●●	●●	●●	●●	●●	●●
Conifer hardwood forest	●●●●●	●●●●	●●●●	●●●●●	●●●●●	●●	●●●	●●●●●	●●●
Mixed coniferous forest	●●●●●	●●●●●	●●●●●	●●●●	●●●●	●●	●●	●●●●●	●●●●
Temperate coniferous forest	●●●●	●●●●●	●●●●●	●●●●●	●●●●	●	●●	●●●	●●●●●
High temperate coniferous forest	●●●	●●●●●	●●●●●	●●●●●	●●●●	●	●●	●●●	●●●●●
Subalpine forest parks	●●●	●●●	●●●●	●●●●	●●●	●	●●	●●	●●●●
Lodgepole pine (Cascade Range)	●●	●●●	●●●	●●●	●●	●	●	●	●●
Shore pine (Coastal)	●	●●	●●●	●●●●	●	●	●	●	●●

1/ Plant and animal diversity is based on the number of species associated with a plant community

Figure 2.—Plant communities and related environmental characteristics. Dots indicate a scale of values from low (one dot) to high (five dots). For example, herbaceous wetland has low plant diversity and high herbage production.

Special and unique habitats that may occur in or adjacent to these communities—such as riparian zones, estuaries, edges, snags, dead and down woody material, caves, cliffs, and talus—are described and discussed in detail in succeeding chapters.

Wetland Types

Three kinds of wetland communities are designated because soil conditions significantly influence wildlife habitat. Soils supporting these communities are saturated with moisture a major part of the year. **Herbaceous wetlands** have less than 60 percent woody cover and are generally dominated by rushes, sedges, and grasses. **Hardwood and shrubby wetlands** have more than 60 percent woody cover commonly dominated by alder, bigleaf maple, willows, Oregon ash, or black cottonwood (fig. 3). The amount of woody vegetation is an important wildlife habitat characteristic. **Coniferous wetlands** are usually dominated by western hemlock, Sitka spruce, or western redcedar. **Coniferous wetland** communities have distinctive ground vegetation such as skunk cabbage, sedges, water parsley or lady-fern. **Coniferous wetlands** are separated from **temperate coniferous forest** because of saturated soil moisture conditions which significantly influence ground-dwelling wildlife.

Figure 3.—Hardwood-shrubby wetland. This plant community may include willows, black cottonwood, alder, bigleaf maple, and sometimes Oregon ash in a riparian setting.

Dryland Types

Dryland plant communities can be divided into two kinds: (1) those that do not or cannot support forest vegetation and (2) forest types.

Nonforested Communities

Grass-forb dry hillsides are mainly caused by humans who control the tree or shrub vegetation. Their primary use is as permanent pasture to feed lifestock, particularly sheep in southwest Oregon.They are designated a "type" because they are maintained in permanent pasture which has a unique set of characteristics for wildlife habitat. Species such as the killdeer, western meadowlark, and common nighthawk are attracted to these habitats. The second nonforest type is **mountain shrubland and chaparral** in which shrubs are less than 15 feet tall and have a crown cover exceeding 40 percent. Lack of trees and presence of shrubs creates wildlife habitat different from open grassland and closed forest.

Forested Communities

Hardwood-dominated Communities
Three plant communities fall into this category—**deciduous hardwood, evergreen hardwood**, and **red alder forest.** Lower valley bottoms, such as the Rogue and Umpqua drainages, Willamette Valley, and Puget Trough commonly have **deciduous hardwoods** dominated by Oregon white oak with occasional conifers (fig. 4). Conifers cannot make up more than 30 percent of the crown cover, and evergreen hardwoods cannot make up more than 50 percent of the crown cover. In southwest Oregon, a community occurs where **evergreen hardwoods** predominate including Pacific madrone, tanoak, golden chinquapin and occasionally, canyon live oak. The vegetation in this community must consist of at least 50 percent evergreen hardwoods, and conifers cannot make up more than 30

Figure 4.—Deciduous hardwood forest of Oregon white oak, poison-oak and grass, typical of lowland valleys.

percent of the stand cover (fig. 5). Height, diameter, and form of deciduous and evergreen hardwood trees are similar. Whether trees retain or lose their leaves, however, is important for wildlife during the winter season; species that retain their leaves provide thermal cover. **Red alder forest,** the third community in this category, commonly develops after disturbance; it creates a unique wildlife habitat within the **temperate coniferous forest**. To be included in this category, red alder must exceed 70 percent composition of the stand.

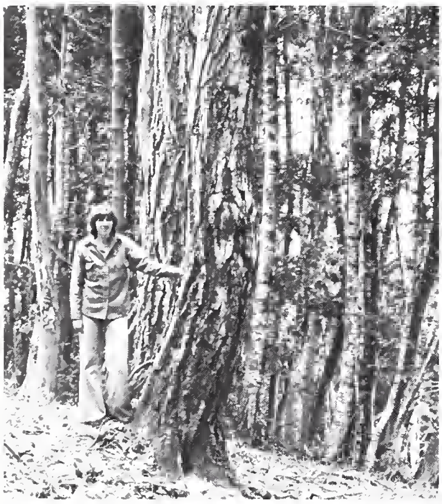


Figure 5.—Evergreen hardwood dominated by tanoak. Tanoak, although often shrubby, can reach large sawtimber size of 21 inches in d.b.h.

Conifer-Hardwood Forest Community **Conifer-hardwood forest** communities occur where hardwoods make up 30 to 70 percent of the tree crown cover (fig. 6). The combination of tall conifers and shorter but codominant hardwood trees creates wildlife habitat different from that of either **red alder forest** or pure coniferous forest. This forest type occurs commonly in southwest Oregon but may also be found at lower elevations in conjunction with the **temperate conifer forest** community, particularly on drier sites in the Willamette Valley and the Puget Sound area. Hardwoods may be deciduous types (such as oak or maple) or evergreen types (such as Pacific madrone or tanoak).

Conifer-Dominated Communities This category covers six of the plant communities identified, including the two that are most widespread. These two are the **temperate** and **high temperate coniferous forest** communities. They include the bulk of the commercially important timber species. The **temperate coniferous forest** community is a combination of the Sitka spruce, western hemlock, and white fir zones (Franklin and Dyrness 1973). It is separated from the **high temperate coniferous forest** community by a transition from the western hemlock zone to the Pacific silver fir, mountain hemlock, and red fir zones which range in elevation from 4,000 feet in southern Oregon to 2,000 feet in northern Washington. Structure of these two types is similar, often being dominated by Douglas-fir with natural regeneration of climax species such as western hemlock in the **temperate coniferous forest** and Pacific silver fir in the **high temperate coniferous forest**. These communities are separated because of wildlife habitat use: **temperate coniferous forest** is winter range with some spring and fall range, often used in the spring for fawning and calving by big game species; **high temperate coniferous forest** is covered with snow during the winter and is primarily used as summer range with some spring and fall habitat for big game. The difference between light and heavy winter snow cover is significant for many nongame wildlife species. A typical old-growth **temperate coniferous forest** is shown in figure 7.

Although several vegetation zones of particular importance to the forest-land manager are combined in the **temperate** and **high temperate coniferous forest** communities, structurally they all present similar habitats for wildlife. If some wildlife species prefer one of these vegetation zones over another, present information on their habitat requirements is not detailed enough to identify the reasons.

Several other distinctive plant communities occur in this category. The **mixed coniferous forest** community is unique to southwest Oregon. Conifers must exceed 70 percent of the crown cover and the stand must be made up of two or more species common on dry sites. Conifers commonly present are

Figure 6.—The conifer-hardwood community with dominant vegetation of Douglas-fir, tanoak, and some Pacific madrone occurs primarily in southwest Oregon.

Figure 7.—Old-growth stand conditions in the temperate coniferous forest plant community are extremely important for some wildlife species such as the spotted owl.

Figure 8.—Mature lodgepole pine community in the Cascades. Simplicity of structure and low diversity of plant species limits this community as wildlife habitat.

Douglas-fir, ponderosa pine, incense-cedar, sugar pine, and white fir. This combination of tree species creates wildlife habitats that are different from those found in other coniferous forest plant communities.

Lodgepole pine, clearly a successional plant community in the **high temperate coniferous forest** zone, has unique habitat characteristics. The community is dominated by a pine having relatively open crown cover and small trunk diameter (fig. 8). In many cases, its structure limits the variety of wildlife species associated with it. Another unique and very restricted plant community is **shore pine.** This is a variety of lodgepole pine that grows along the Pacific shore in salt-spray conditions. Its short stature, the salt-spray influence, and the location create a unique wildlife habitat.

Finally, **subalpine forest parks** are a general category representing a complex of plant communities characteristic on noncommercial forest land at upper elevations. They are dominated by mountain hemlock, whitebark pine, or subalpine fir. Forest stands tend to be open and, in many cases, appear as stringers or clumps in nonforest or rocky areas. High elevation and abundant inherent edge are important characteristics of wildlife habitat in these areas.

Stand Conditions

Structure of a plant community may be determined either by the physical growth characteristics or by the size and age of plant species making up the community (fig. 9). For example, a grassland plant community provides completely different wildlife habitats than does a Douglas-fir community in its mature stage, but the same forest community in the grass-forb condition with fully stocked Douglas-fir regeneration provides wildlife habitats very similar to the grassland plant community. Forest plant communities, when altered by timber management programs, exhibit a variety of stand conditions.

Forest stands may be treated silviculturally for a variety of purposes. For example, they may be regenerated by clearcut or shelterwood systems and the area planted or treated to facilitate natural regeneration. Other stands may be precommercially thinned, salvaged for dead and dying material, commercially thinned to remove harvestable products, or selectively treated to remove unwanted tree species. Sanitation and salvage cutting removes dead and dying trees that would become standing snags under natural conditions and, eventually, down woody material. As a result, silvicultural treatment can have a profound influence on wildlife habitat.

Down woody material is desirable for many wildlife species (Franklin et al. 1981, Maser et al. 1981). The amount of woody material varies tremendously between plant communities and within the same plant community, depending on how the community developed and the silvicultural treatment it received. A forest developing under natural conditions has a far greater volume of woody material than does one that has been intensively managed. For example, Maxwell and Ward (1980) found from 105 to 330 tons of woody material per acre on old-growth stands in the temperate coniferous forest community. In an intensively managed stand where potential snags and down woody material are removed prior to or during timber harvest, and when the stand is harvested while in the large sawtimber stand condition, residue loadings consist of smaller materials and may be only 7 to 25 tons per acre (Maxwell and Ward 1976). These differences carry over and affect the amount of woody material in succeeding stand conditions.

The type of logging system used and the cleanup after logging also significantly influences the amount of down woody material left on an area. After clearcutting of old-growth stands in the temperate coniferous forest plant community, residues ranged from as little as 7 tons per acre with tractor piling and burning, to as much as 223 tons per acre with high-lead yarding and no residue reduction (Maxwell and Ward 1976). Precommercial and commercial thinning adds from 9 to 60 tons of small diameter residue per acre. For a detailed discussion of the importance of down woody material as wildlife habitat, see chaper 8.

When areas are clearcut, treatment of logging slash has a significant effect on which plant species colonize the unit. Broadcast burning can stimulate sprouting of shrubs, break dormancy of ceanothus and legume seeds and prepare an excellent seedbed for windblown seed. Yarding with a skyline system and not burning unmerchantable material that remains, does not prepare a good seedbed for windblown seed, does not stimulate seeds to germinate, and does not encourage sprouting. Such a unit may produce little vegetation for 3 to 5 years, limiting cover and forage for wildlife.

Shelterwood systems generally do not create the same types of wildlife habitat as clearcuts do and may not result in a similar sequence of vegetative conditions. A shelterwood is designed to modify the microclimate by retaining tree cover—up to 40 percent tree canopy—to enhance tree regeneration. In some cases, advanced tree regeneration of climax species may comprise a majority of the seedlings. When the shelterwood overstory is removed, the residual vegetation may already be in the "open sapling-pole stage," completely bypassing the grass-forb and shrub stages.

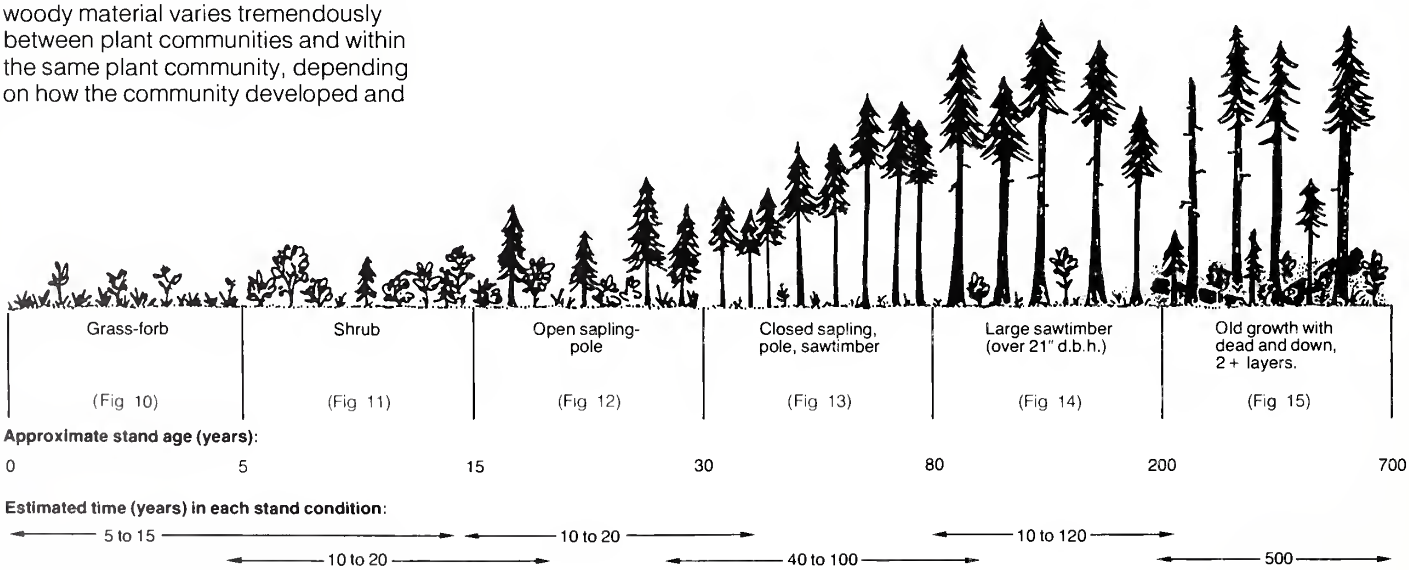


Figure 9.—Stand conditions in temperate coniferous forest after clearcutting and broadcast burning. An example of each stand condition is shown in the figures indicated.

The following descriptions of stand conditions and time intervals that vegetation may be expected to stay in a stand condition are based on conditions that normally develop after broadcast burning of slash in the temperate and high temperate coniferous forest plant communities (fig. 9). Modifications of these descriptions may be required when used with other plant communities or with other silvicultural treatments. More detailed descriptions and actual definitions for each stand condition are given in appendix 6.

Grass-Forb Stand Condition

The grass-forb stand condition lasts 2 to 5 years and occasionally as long as 10 years (fig. 10). After timber harvest and/or slash removal, the unit may be largely devoid of vegetation for the first growing season. Resident herbs and new plants from windblown seed, however, quickly dominate the site and give the unit a grass-forb appearance. Shrubs and some trees that sprout are not yet dominant.

Figure 10.—Grass-forb stand condition on a clearcut area within the temperate coniferous forest plant community. Edge is created between these two stand conditions.

Shrub Stand Condition

The shrub stand condition often lasts 3 to 10 years but may remain for 20 to 30 years if tree regeneration is delayed (fig. 11). Shrubs become the dominant vegetation providing habitat for wildlife that is different from the grass-forb stand condition. Tree regeneration may be common, but trees are generally less than 10 feet tall and provide less than 30 percent of the crown cover.

Figure 11.—Shrub stand condition with a few tree seedlings showing. This condition commonly lasts 3 to 10 years or longer in the temperate coniferous forest plant community. This also illustrates the large amount of woody debris that may remain after an old-growth forest stand is logged.

Open Sapling-Pole Stand Condition

The open sapling-pole stand condition occurs when trees exceed 10 feet in height but still have less than 60 percent crown canopy when they reach 1 inch in d.b.h. (fig. 12). A dominant shrub understory is common. This open sapling-pole condition is very different wildlife habitat from closed sapling-pole where tree crown cover exceeds 60 percent at 1 inch in d.b.h. or larger. The open sapling-pole stage may be bypassed if initial tree densities exceed 400 trees per acre. In addition, open sapling-pole can be the first stand condition after overstory removal in shelterwood regeneration. The grass-forb and shrub stand conditions may be bypassed because residual tree cover does not create an opening. On the other hand, the open sapling-pole stand condition, which provides habitat for many species of wildlife, can be maintained or created with precommercial thinning. Length of time in this condition depends on tree crown closure and subsequent stand treatment. It may last from 8 to 20 years.

Figure 12.—Open sapling-pole stand condition in temperate coniferous forest. Trees exceed 10 feet in height but produce less than 60 percent crown cover.

Figure 13.—Closed sapling-pole-sawtimber stand condition in temperate coniferous forest. Tree crown cover exceeds 60 percent.

Closed Sapling-Pole-Sawtimber Stand Condition

Closed sapling-pole-sawtimber stand conditions have one item in common—very little ground vegetation because of a closed crown canopy (fig. 13). Tree crown cover will exceed 60 percent and often reaches 100 percent. These conditions are more important than average stand d.b.h. or stand height in determining the type of wildlife habitat provided. Length of time in this stand condition can range from 40 to 100 years. The time is determined by rotation age and thinning treatment. If stands are thinned and long rotations used, this stand condition can change to large sawtimber or eventually old growth.

Figure 14.—Large sawtimber stand condition in temperate coniferous forest. Tree average d.b.h. is 21 inches or larger, they have nearly closed crown cover, and they produce little dead and down material.

Large Sawtimber Stand Condition

The large sawtimber stand condition is characterized by trees with an average d.b.h. of 21 inches or larger that create a different wildlife habitat than smaller stands. Conifers usually exceed 100 feet in height, and their crown cover is generally less than 100 percent, permitting the development of ground vegetation (fig. 14). With this stand condition under intensive timber management, diameters of trees may approach diameters of old growth but the very large snags and high volumes of large down material characteristic of old growth will be lacking. Natural large sawtimber stands can have nearly as much standing and down woody material as old-growth stands. Duration of this stand condition is determined by rotation age and thinning treatments. If mortality and decay are regularly prevented by thinning, this condition lasts for many years; but such a stand will lack the snag component necessary for cavity nesters and the down woody material essential for many wildlife species.

Figure 15.—Old-growth stand conditions in temperate coniferous forest includes both pioneer Douglas-fir and climax western hemlock. Decay in living trees is common, as are snags and down woody material.

Old-Growth Stand Condition

Old-growth stand conditions are characterized by decadence of live trees, snags, down woody material, and replacement of some of the long-lived pioneer species such as Douglas-fir by climax species such as western hemlock. Stands often have two or more layers with large diameter overstory trees commonly older than 200 years. Crown closure is normally less than 100 percent (Franklin et al. 1981) (fig. 15).

Discussion

Old growth may not be climax. Optimum wildlife habitat in old-growth stands, as described by Franklin et al. (1981), specifically requires a component of pioneer Douglas-fir mixed with western hemlock. The old-growth Douglas-fir has crown and bark characteristics quite different from western hemlock. These features of Douglas-fir are highly significant as habitat for certain wildlife species such as bats and the western red-backed vole.

Figure 16 characterizes various attributes of different stand conditions in the temperate coniferous forest.

The type of plant community influences structure and length of time for each of the above stand conditions. When a forest is clearcut and broadcast burned, the initial stand condition is grass-forb, a condition similar in all plant communities; however, length of time in the grass-forb stand condition and species composition of the shrub stand condition can vary dramatically between communities. For instance, the evergreen hardwood plant community is composed of tree species capable of sprouting, whereas most tree species in the temperate coniferous forest community are not. Evergreen hardwood can change from grass-forb to shrub stand conditions in 2 to 3 years with vigorous sprouting of tanoak, canyon live oak, or Pacific madrone. The shrub stand condition may last only 5 years until trees exceed 15 feet in height—a total time span in "open conditions" of 5 or 6 years. Compare this with 20 to 30 years for grass-forb plus shrub stand conditions in the temperate coniferous forest plant community where initial tree regeneration has failed. If stands are treated to create wildlife openings, an understanding of the time the area will remain in grass-forb or shrub condition is needed.

In contrast to the similarity between plant communities in grass-forb and shrub conditions, old-growth structure varies widely among the various communities. For example, lodgepole pine and shore pine, which seldom reach 21 inches in d.b.h., rarely meet the definition of large sawtimber or old growth. Figure 15, showing temperate coniferous old growth with a partial overstory of 500-year-old Douglas-fir and understory of western hemlock, is not the same "old growth" as an evergreen hardwood stand dominated by tanoak, such as the one shown in figure 5.

Silvicultural treatments other than clearcutting are often applied to forest stands for regeneration purposes. Figure 17 depicts a shelterwood system that leaves 80 square feet of basal area per acre and 40 percent crown cover of trees. This stand condition does not provide the same wildlife habitat as the grass-forb or shrub stand condition with their full sunlight, brisk wind movement, and open sky desired by many wildlife species. In a

Stand conditions	Plant diversity 1/	Vegetation height	Canopy volume	Canopy closure	Structural diversity	Herbage production	Browse production	Animal diversity 1/	Woody debris (natural) 2/	Woody debris (intensive management) 2/
Grass-forb	●●●	●	●	●	●	●●●●●	●	●●	●●●●●	●
Shrub	●●●●	●●	●●	●●	●●	●●●●	●●●●●	●●●●●	●●●●	●
Open sapling-pole	●●●●	●●●	●●●	●●●	●●●●	●●●	●●●	●●●●	●●●	●
Closed sapling-pole sawtimber	●	●●●●	●●●●	●●●●●	●●	●	●	●	●●	●●
Large sawtimber	●●●	●●●●●	●●●●●	●●●●	●●●	●●	●●	●●●	●●●	●●
Old growth	●●●●●	●●●●●	●●●●	●●●●	●●●●●	●●●	●●●	●●●●	●●●●●	●●●●●

1/ Plant and animal diversity is based on the number of species associated with a stand condition

2/ Amount of woody debris can vary depending on treatment after clearcutting (Maxwell and Ward 1976).

Figure 16.—Stand conditions and related environmental characteristics in temperate coniferous forest. Dots indicate a scale of values from low (one dot) to high (five dots).

shelterwood, the overstory is often retained until regeneration reaches 4 to 6 feet in height. This effectively eliminates grass-forb and greatly reduces time in the shrub condition. If "nonforest" wildlife habitat is desired, shelterwood regeneration will probably not create suitable conditions.

The degree of heterogeneity within a plant community is also extremely important in determining the value of that community as wildlife habitat. A variety of stand conditions within a plant community creates edge between stand conditions and greater diversity of wildlife habitats than does a large homogeneous expanse of one plant community or one stand condition. In western Oregon and Washington, timber management activity is the primary factor in determining the size and spacing of stand conditions within forest communities. The importance of size and distribution of stand conditions will be discussed in detail in chapters 6 ("Edges") and 14 ("Silvicultural Options").

Figure 17.—Shelterwood regeneration system. In the temperate coniferous forest community, mature trees with 40 percent crown cover and 80 square feet of basal area per acre are left to protect new seedlings. If this overstory is removed after seedlings reach at least 4 feet in height, the grass-forb stage will be bypassed and the shrub condition will last only a few years.

References Cited

Franklin, J. F.; Dyrness, C. T. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1973. 417 p.

Franklin, J. R.; Cromack, K., Jr.; Dension, W. [and others]. Ecological characteristics of old-growth Douglas-fir forests. Gen. Tech. Rep. PNW-118. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 48 p.

Küchler, A. W. Manual to accompany the map, potential natural vegetation of the conterminous United States. New York: Am. Geogr. Soc. Spec. Pub. 36. [152 p. 2d ed. Map, 1975] 1964.

Maser, C.; Mate, B. R.; Franklin, J. F.; Dyrness, C. T. Natural history of Oregon coast mammals. Gen. Tech Rep. PNW-133. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 496 p.

Maxwell, W. G.; Ward, F. R. Photo series for quantifying forest residues in the coastal Douglas-fir-hemlock type, coastal Douglas-fir-hardwood type. Gen. Tech. Rep. PNW-51. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1976. 103 p. illus.

Maxwell, W. G.; Ward, F. R. Photo series for quanitfying natural forest residues in common vegetation types of the Pacific Northwest. Gen. Tech. Rep. PNW-105. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 229 p. illus.

Mueller-Dombois, D.; Ellenberg, H. Aims and methods of vegetation ecology. New York: John Wiley and Sons; 1974. 547 p.

Thomas, J. W.; Miller, R. J.; Maser, C. [and others]. Plant communities and successional stages. In: Thomas, J. W., ed. Wildlife habitats in managed forests-the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979: 22-39.

3

Wildlife Relationships to Plant Communities and Stand Conditions

Charles Bruce
Dan Edwards
Kim Mellen
Anita McMillan
Tom Owens
Harold Sturgis

Table of Contents

Introduction

Habitat conditions are the prime determinants of wildlife abundance both in the number of species and the number of individuals. The abundance of most wildlife species is directly dependent upon the condition of available habitat, whether used for breeding, feeding, or resting (shelter).

Forest management activities have significant impacts on habitat conditions for many wildlife species. To evaluate these impacts, the land manager must know which wildlife species are associated with which plant communities and stand conditions within those communities, which species are most vulnerable and those that are least affected by habitat alteration, and finally, which species occur on a site only because of the presence of a special or unique habitat. The portrayal of the relationships of wildlife to habitat, the subject of this chapter, is similar to that used by Thomas (1979).

Key concepts more fully discussed in chapter 2 bear repeating here. Vegetation structure, rather than plant species composition, is often the primary determinant of habitat preference by wildlife. For example, common ravens prefer large sawtimber or old-growth trees for nesting, and satisfy this preference equally well in any of nine plant communities, with no apparent preference for any individual tree species.

Vegetation conditions resulting from forest management activities can be structurally similar to stages of plant succession which follow natural phenomena such as wildfire. Consequently, knowledge of the relationships between wildlife and stages of natural plant succession can be used to anticipate the immediate effects of forest management activities on wildlife (fig. 1). One can generally determine which wildlife species will be benefited and which adversely affected over time on the continuously changing mosaic of habitats typical of managed forests. These stages of plant succession, which naturally occur in native plant communities, provide the basis for displaying wildlife-to-habitat relationships in terms of plant communities and stand conditions.

Figure 1.—Typical forest harvesting activities in western Oregon and Washington result in the conversion of mature or old-growth forests to grass-forb stand conditions. Impacts on wildlife are extreme but forest managers can minimize long term negative effects.

In addition to the array of habitats provided by plant community and stand conditions, there are special and unique habitats. More than half of all wildlife species considered in this volume are represented as using special or unique habitats for feeding, and nearly a third use such habitats for breeding (fig. 2). Special and unique habitats may be vegetated or unvegetated features of the environment that have value as wildlife habitat not specifically attributable to plant communities or successional stages. Many species of wildlife use special or unique habitats in a manner entirely independent of the kind or condition of surrounding vegetation, although it is rare that such a habitat satisfies all of the species' needs. The peregrine falcon and black swift, for example, are cliff-nesting species that choose nest sites with no apparent relationship to adjacent vegetation. Similarly, the tree swallow nests in tree cavities based on availability of such cavities without regard to the plant community or successional stage in which the tree is found. The pileated woodpecker, on the other hand, is entirely dependent for its livelihood on a special habitat component occurring within rather specific stand conditions. It needs large dead trees within stands of large sawtimber or old growth to excavate cavities for breeding and feeds primarily on insects found in the dead wood that is a common component of these stand conditions.

Figure 2.—More than half of all forest wildlife species use special and unique habitats. The Ensatina salamander uses logs, downed material, and talus.

The vulnerability of special and unique habitats to timber management activities varies greatly. Snags and dead and down woody material may be entirely lost during timber harvest unless an effort is made to preserve them. The usefulness of riparian zones will largely be lost and the flow, temperature, and quality of a perennial stream modified, by removal of riparian vegetation. Unique habitats such as caves, cliffs, and talus may remain unchanged by removal of surrounding vegetation but their microclimates and usefulness as habitat for certain wildlife species may change. Special and unique habitats should always be considered in management of forest wildlife, whether the objective is to maintain maximum species diversity or to favor individual species.

The number and variety of forest conditions to which wildlife are adapted vary widely between species, and the response of a wildlife species to habitat change is directly related to its range of behavioral and morphological adaptations. Populations of those species that successfully reproduce and feed in a wide variety of plant communities and stand conditions typical of a managed forest are less likely to experience significant decline with any given change because of the array of options available to them. Species dependent on only one plant community, one stand condition, or one special habitat that is limited in size, distribution, or abundance are much more vulnerable. The hazards such species face are considerable if the required habitat is likely to be dramatically altered or eliminated by a forest management practice.

In the case of both the more versatile species and species adapted to very specific habitats, requirements for reproduction tend to be more specialized than for feeding or resting. Therefore, those species that reproduce within the forested areas of western Oregon and Washington tend to be more vulnerable to the effects of forest practices than are those species that only winter in, or migrate through the area and breed elsewhere.

The manager of forest land who seeks to assess the effects of a proposed management action on wildlife is faced with a complex task. The environment is varied and dynamic, the number of species large, and their habitat requirements diverse. The manager needs a method to determine which species are adversely affected, unaffected, or benefited. The degree and duration of effects must be estimated. Irreversible impacts must be known, as well as those impacts which may be eliminated or ameliorated by appropriate management. In addition, those species most sensitive to change must be identified and the manager must know how the action would affect species that are classified as threatened or endangered.

Data Collection and Display

Compilation of information to serve as a basis for evaluating fish and wildlife relationships to forest management activities was accomplished in two basic steps. The first step required a determination of species that use habitats in western Oregon and Washington. Using standard checklists and references, lists of vertebrate wildlife, freshwater fish, and selected marine fish were compiled. Wildlife species are shown in appendix 1 and the freshwater and selected marine fish species are shown in appendix 2.

The second step involved assembling pertinent information concerning life history and habitat use for these fish and wildlife species. Wildlife species life history and habitat preference information are presented in appendix 8 while similar information for fish is presented in appendices 9, 10, and 11.

The data on habitat use and other aspects of life history were compiled from the literature using publications of a broad and general nature as well as detailed life history studies and published research dealing with one or only a few aspects of a species' natural history. Sources specific to the region covered by this publication were used when available. In those instances where little or no regional data were available, information from other areas was used if, in the judgment of the reviewing biologists, it was applicable to this region.

No attempt was made to exhaust all existing sources of information. The literature search was most intensive in the case of species for which published data are limited, and less intensive in the case of species that have been more thoroughly studied. Complete information on the life history of many species is simply lacking. Development of the information presented in the appendices often required judgements made by concensus, based on individual knowledge and experience. Data assembled for all the species included in the matrices were reviewed by biologists with both broad and specific expertise throughout the region.

This approach displays wildlife orientation to habitats that are potentially suitable within the region. Comments on species distribution in most cases indicate only whether a species occurs

in western Washington, western Oregon or both. The region included is vast, and it cannot always be assumed that a particular species is present throughout based solely on the presence of suitable habitat. For example, the brush rabbit is a common species widely distributed in several plant communities throughout much of western Oregon, yet it is not known to occur in apparently identical habitats anywhere in western Washington.

Patterns of seasonal occurrence and activity differ greatly among the bats and many birds occurring in the region. With a few exceptions, the primarily insectivorous birds such as flycatchers, warblers, and swallows occur only during the breeding season and winter elsewhere. Of 29 species of waterfowl, 11 species regularly occur in the region only during migration or as winter residents. The remaining species breed within the region and, with the exception of the blue-winged teal, are regular winter residents. Say's phoebe and the rough-legged hawk are examples of species which are not known to breed in the region, but are present during winter or migration. In addition, seasonal use of habitats by individual species varies within the region with differences in latitude and elevation. Although these variations are accounted for in the matrices to the extent permitted by the format, they are generalized, and the user should be alert to the possibility of local variations.

Because of the vast area for which the data were accumulated, and other limitations, resolution is less when the size of the area considered for management is small. The forest land manager should recognize that these appendices cannot substitute for local knowledge or field inventory, but should be viewed as a broad information base that will aid the development and refinement of localized project assessments and plans (fig. 3).

Because appendices 1, 2 and 8 provide much of the basic information needed in determining how wildlife species will react to forest management actions, the reader is urged to develop a thorough familiarity with their elements. The two following sections discuss the elements of these appendices and how the information that appears in them was developed.

Figure 3.—The presence of apparently suitable habitat is no substitute for local knowledge. The brush rabbit is widely distributed in several plant communities in western Oregon yet does not occur in similar habitats in western Washington.

Appendices 1 and 2 (Species lists)

Appendix 1 includes 460 species of vertebrate wildlife that were identified as using habitats in western Oregon and Washington. An example of appendix 1 is shown in table 1. Appendix 2 lists 178 freshwater and selected marine fish species with an example of this appendix presented in table 2. Excluded from the lists were strictly pelagic wildlife species and marine fish species that utilize habitats not normally affected by land-based operations. All species were assigned to one of four categories depending upon how their habitat might be affected by forest management activities. Species whose habitat could be affected by forest manipulation but at sites removed from the actual forest activity were marked with a single asterisk (*) (fig. 4). Those species whose habitat requirements are such that there is only a slight chance of forestry related impacts are marked with a double asterisk (**). The final category, marked with three asterisks (***), includes casual visitors, very rare species and those whose occurrence status in western Oregon and Washington has not been determined (fig. 5). Those whose habitat requirements are such that their reproduction, distribution, or forage base would be affected at the site of the forest manipulation were not marked.

Figure 4.—Sixty-two species, including most shorebirds, can be affected by forest management activities at sites removed from the location where the activity takes place.

Table 1 — An example of information contained in appendix 1

460 wildlife species found west of the crest of the Cascade Range in Oregon and Washington listed in phylogenetic sequence by common and scientific names

Appendix 1 lists in phylogenetic order the common and scientific names of the 460 species of wildlife found west of the crest of the Cascade Range in Oregon and Washington. The computer letter code for each species and the life form group to which that species was assigned also are shown. Excluded were strictly pelagic species that are rarely found in westside habitats.

All species were assigned to one of four categories as follows:

Unmarked – Species whose habitat requirements are such that forestry practices will impact their reproduction, distribution or forage base at the site of the forest manipulation.

* Species whose habitat requirements are such that impacts of forestry practices on their distribution or forage base will occur at sites removed from the immediate area of forest manipulation.

** Species whose habitat requirements are such that there is only a slight chance of forestry related impacts.

*** Casual, very rare species, or those whose occurrence status is undetermined at this time.

Species in the two and three asterisk categories usually are not included in other appendices although some of them are discussed under specialized habitats.

Order & Family Letter Code	Life Form	Common Name	Scientific Name
AMPHIBIANS[1]			
CAUDATA: Ambystomatidae — Mole Salamanders			
AMGR	2	northwestern salamander	*Ambystoma gracile*
AMMA	2	long-toed salamander	*Ambystoma macrodactylum*
DICO	1	Cope's giant salamander	*Dicamptodon copei*
DIEN	2	Pacific giant salamander	*Dicamptodon ensatus*
RHOL	2	Olympic salamander	*Rhyacotriton olympicus*
Plethodontidae — Lungless Salamanders			
ANFE	5	clouded salamander	*Aneides ferreus*
ANFL	5	black salamander	*Aneides flavipunctatus*
BAAT	5	California slender salamander	*Batrachoseps attenuatus*
BAWR	5	Oregon slender salamander	*Batrachoseps wrighti*
ENES	5	Ensatina	*Ensatina eschscholtzi*
PLDU	3	Dunn's salamander	*Plethodon dunni*
PLEL	4	Del Norte salamander	*Plethodon elongatus*
PLLA	4	Larch Mountain salamander	*Plethodon larselli*
PLEST	4	Siskiyou Mountains salamander	*Plethodon stormi*
PLVA	3	Van Dyke's salamander	*Plethodon vandykei*
PLVE	5	western redback salamander	*Plethodon vehiculum*
Salamandridae — Newts			
TAGR	2	roughskin newt	*Taricha granulosa*
ANURA: Bufonidae — True Toads			
BUBO	2	western toad	*Bufo boreas*
Hylidae — Treefrogs			
HYRE	2	Pacific treefrog	*Hyla regilla*
Leiopelmatidae—Bell Toads			
ASTR	2	tailed frog	*Ascaphus truei*
Ranidae — True Frogs			
RAAU	2	red-legged frog	*Rana aurora*
RABO	2	foothill yellow-legged frog	*Rana boylei*
RANCA	2	Cascade frog	*Rana cascadae*
RACAT	1	bullfrog	*Rana catesbeiana*
RAPR	2	spotted frog	*Rana pretiosa*
REPTILES[1]			
TESTUDINES: Emydidae — Water and Box Turtles			
CHPI	3	painted turtle	*Chrysemys picta*
CLMA	3	western pond turtle	*Clemmys marmorata*
SQUAMATA: (suborder Lacertilia) Anguidae — Anguids			
ELCO	5	northern alligator lizard	*Elgaria coerulea*
ELMU	5	southern alligator lizard	*Elgaria multicarinata*
Iguanidae—Iguanids			
PHDO	5	short-horned lizard	*Phrynosoma douglassi***
SCEGR	5	sagebrush lizard	*Sceloporus graciosus*
SCOC	5	western fence lizard	*Sceloporus occidentalis*

[1] After Nussbaum et al. 1983.

Table 2 — An example of information contained in appendix 2

178 freshwater and selected marine fish species found west of the crest of the Cascade Range in Oregon and Washington listed in phylogenetic sequence by common and scientific names

Appendix 2 lists in phylogenetic order the common and scientific names of 178 freshwater and selected marine fish species found in waters west of the crest of the Cascade Range in Oregon and Washington. The computer letter code, the life form group to which that species was assigned,and occurrence code for each species also are shown.

All species were assigned to one of four categories as follows:

Unmarked – Species whose habitat requirements are such that forestry practices will impact their reproduction, distribution or forage base at the site of the forest manipulation.

* Species whose habitat requirements are such that impacts of forestry practices on their distribution or forage base will occur at sites removed from the immediate area of forest manipulation.

** Species whose habitat requirements are such that there is only a slight chance of forestry related impacts.

*** Casual, very rare species, or those whose occurrence status is undetermined at this time.

Species in the two and three asterisk categories usually are not included in other appendices although some of them are discussed under specialized habitats.

Order & Family Letter Code	Life Form	Common Name	Occurrence[1]	Scientific Name
FRESH WATER AND SELECTED MARINE FISH [2]				
PETROMYZONTIFORMES: Petromyzontidae — Lampreys				
LAAY	1-E	river lamprey	F-S	*Lampetra ayresi*
LARI	1-E	western brook lamprey	F	*Lampetra richardsoni*
LATR	1-E	Pacific lamprey	F-S	*Lampetra tridentata**
SQUALIFORMES: Squalidae — Dogfish Sharks				
SQAC	1-A	spiny dogfish	S	*Squalus acanthias**
RAJIFORMES: Rajidae — Skates				
RABI	1-E	big skate	S	*Raja binoculata***
RARH	1-E	longnose skate	S	*Raja rhina***
CHIMAERIFORMES: Chimaeridae — Chimaeras				
HYCO	1-E	spotted ratfish	S	*Hydrolagus colliei****
ACIPENSERIFORMES: Acipenseridae — Sturgeons				
ACME	1-G	green sturgeon	S-F	*Acipenser medirostris**
ACTR	1-G	white sturgeon	F-S	*Acipenser transmontanus*

[1] F = Inhabits freshwater
S = Inhabits saltwater
F-S = Found in both fresh and saltwater with its primary habitat indicated by the letter which appears first.
A = Anadromous.

[2] After Robins et al. 1980.

Figure 5.—The great gray owl was only recently found to breed in southwestern Oregon but its status in the area remains undetermined.

Species are grouped taxonomically and listed in phylogenetic order. Classes are separated by order and family. For each species the following information is shown: letter code, life form, common name, and scientific name. With the fish species list (appendix 2) an additional occurrence code is included that indicates whether the species is found in freshwater (F), saltwater (S), both fresh and saltwater (F-S) or is anadromous (A).

Letter Code

Letter codes, designed to aid in computer analysis of data, are based on the scientific name and usually consist of the first two letters of the genus name and the first two letters of the species name. When conflicts develop a fifth or sixth letter is added in order to create a unique code for that species.

Life Form

Each species was assigned to one of the 16 life forms developed by Thomas (1979) that best describes its breeding and feeding adaptations (table 3). Within life form 1, 8 additional forms designated 1-A through 1-H have been developed to describe more precisely the breeding and feeding adaptations of fishes and invertebrates (see chapters 5, 10 and appendices 11 and 12).

The life form concept groups together species exhibiting specific combinations of habitat requirements for breeding and feeding. Thomas (1979) assumed that all species within a life form respond similarly to a given habitat change and that the manager would find the concept more useful in evaluating the response of wildlife to habitat than considering each species individually.

In this document, habitat orientation by life-form groups is not presented because of apparent variable responses of many species to habitat change. For example the spotted owl, western bluebird, marten, purple martin, and northern flying squirrel all are found within life form 14 but respond differently to forest management because of different habitat and behavioral needs. Each species is assigned a life form, however, should the user choose to construct life-form tables (fig. 6).

Figure 6.—The northern flying squirrel (above), spotted owl, black-capped chickadee, and house wren all are found within the same life form yet differ greatly in their ability to respond to habitat changes.

Common Name

This column shows the common name for each species as determined from standard checklists. This is the name by which species are identified throughout this volume.

Scientific Name

This column includes the genus and species names for all species considered. Subspecies are not considered except in rare cases, usually where a threatened or endangered species is involved.

Appendix 8 (Wildlife/habitat Relationships)

Appendix 8 is a tabular presentation of vertebrate wildlife species life history and habitat requirements that serves as the foundation for this publication. The appendix is set up in a series of 38 four-page matrices with data for an individual species carrying continuously through the four pages of the matrix. Species are listed by taxonomic groups and in phylogenetic order as they are in appendix 1. The 46 species designated with two or three asterisks are not included, however, because their habitat preferences or other factors are such that there is very little possibility of forestry related impacts. Fish and estuarine invertebrate species are covered in detail in chapters 5, 10, and appendices 9, 10, 11, and 12. They are not discussed further in this section.

Table 4 presents an example of the four page matrix and for convenience of discussion the four pages are labeled A, B, C, and D. The elements of the matrix are discussed in their order of appearance.

Table 4, Page A (Example of the first page of the appendix 8 matrix)

Species, Letter Code, and Life Form Species are identified by the common name and letter code. Also shown is the life form to which the species is assigned. This information is taken directly from appendix 1.

Versatility Rating The versatility rating is an indicator of the sensitivity of each species to habitat change. The rating was developed by adding the number of plant communities and stand conditions to which a species has a primary or secondary breeding or feeding orientation. Use of special and unique habitats was not considered in calculating

Table 3 — An example of information contained in appendix 7

Life Form Descriptions [1]

Life form	Reproduces	Feeds	No. of Species [2]	Examples
1 [3]	in water	in water	3	Cope's giant salamander, bullfrog, sea otter
1-A	in water column (eggs, larvae, and juvenile forms are planktonic and the adult form is mobile)	in water column	26	American shad, Olympic mudminnow, copepod
1-B	in water column (adult form is sedentary)	in water column	17	native oyster, butter clam, geoduck clam
1-C	in water column (adult form is mobile)	in or on substrate	50	striped bass, starry flounder, tube worm, Dungeness crab
1-D	in water column (adult form is sedentary)	in or on substrate	7	peanut worm, macoma clam
1-E	in or on substrate (eggs, larvae, or juvenile forms deposited on substrate and the adult form is mobile)	in water column	91	chinook salmon, common carp, smallmouth bass
1-F	in or on substrate (adult form is sedentary)	in water column	0	(sea anemone) [4]
1-G	in or on substrate (adult form is mobile)	in or on substrate	64	white sturgeon, prickly sculpin, periwinkle snail, amphipod
1-H	in or on substrate (adult form is sedentary)	in or on substrate	3	segmented worm, lug worm
2	in water	on the ground, in bushes, and/or in trees	12	northwestern salamander, Pacific treefrog, spotted frog
3	on the ground around water	on the ground, and in bushes, trees, and water	107	western pond turtle, mallard, glaucous-winged gull, Pacific jumping mouse
4	in cliffs, caves, rimrock, and/or talus	on the ground or in the air	31	Del Norte salamander, peregrine falcon, bobcat
5	on the ground without specific water, cliff, rimrock or talus association	on the ground	68	ensatina, ruffed grouse, dark-eyed junco, elk
6	on the ground	in bushes, trees, or the air	8	common nighthawk, Wilson's warbler, porcupine

Table 4, page A – An example of information contained in appendix 8

Occurrence and orientation of 414 wildlife species to western Oregon and Washington plant communities, stand conditions, and special or unique habitats

Species [1]	Letter code [1]	Life form [2]	Versatility rating [3]	Habitat use [4]	Seasonal occurrence and activity: January	February	March	April	May	June	July	August	September	October	November	December	Comments [5]
AMPHIBIANS																	
northwestern salamander	AMGR	2	19	B													Breeds early in lowlands and later at higher elev. Requires quiet water for breeding. Larvae often neotenic. Uncommon to common, W. WA. and W. OR.
				F													
				Rs													
long-toed salamander	AMMA	2	19	B													Breeding occurs early in lowlands and later at higher elev. Requires quiet water for breeding and down logs or rock near water for cover. Uncommon to common in suitable habitat. W. WA. and W. OR., except central Oregon coast and Coast Ranges.
				F													
				Rs													
Cope's giant salamander	DICO	1	*	B													Breeding habits unknown, but should be similar to Olympic salamander. Not known to metamorphose in nature, remains aquatic. Olympic Mts., Willapa Hills, and SW Cascades of WA. and the Columbia R. Gorge, OR.
				F													
				Rs													
Pacific giant salamander	DIEN	2	17	B													Requires cold, clear, well oxygenated water for breeding. Common in suitable habitat. W. WA. and W. OR.
				F													
				Rs													
Olympic salamander	RHOL	2	13	B													Restricted to cold, rocky, permanent springs, seepages, and small streams. Common in suitable habitat. W. WA. and W. OR.
				F													
				Rs													
clouded salamander	ANFE	5	22	B													Hibernation may occur Dec.- Jan. Requires abundant ground litter and a moist microhabitat for breeding and feeding. Common resident of W. OR.
				F													
				Rs													
black salamander	ANFL	5	18	B													Hibernation may occur Dec.- Jan. Requires moist habitat with rock or ground debris, preferably near streams or seepages. Rare in the Applegate River Valley, OR., which is the northern limit of its range.
				F													
				Rs													
California slender salamander	BAAT	5	26	B													Found in moist soil under litter, logs, and rocks. SW OR. only, common in preferred habitat.
				F													
				Rs													
Oregon slender salamander	BAWR	5	20	B													Dependent on woody debris of various types for feeding and reproduction. Decaying fir logs seem to be preferred. Uses talus in Columbia River Gorge. Uncommon, but may be locally abundant. Oregon Cascades south to Oakridge.
				F													
				Rs													

B-Breeding; F-Feeding; Rs-Resting; See comments and Chapter 3 narrative.

*Indicates a species has little orientation to plant communities or stand conditions and occurs there only if a special or unique habitat is available Versatility ratings were not developed for these species.

See footnotes at end of appendix. *Appendix 8*

Species [1]	Specific data [6]	Habitat use [4]	Coastal: Saltwater (ocean)	Coastal: Estuary	Coastal: Saltwater beaches	Coastal: Freshwater beaches	Riparian: Rivers	Riparian: Streams and creeks	Riparian: Sloughs	Riparian: Springs	Riparian: Lakes	Riparian: Ponds	Riparian: Reservoir	Wetlands: Ponds	Wetlands: Marshes, swamps, bogs	Wetlands: Seeps	Wetlands: Wet meadows	Edges: Grass - shrub	Edges: Shrub - forest	Edges: Grass - forest	Edges: Water - grass	Edges: Water - shrub	Edges: Water - forest	Habitat features: Snags	Habitat features: Logs & down material	Habitat features: Cliffs	Habitat features: Talus	Habitat features: Caves
AMPHIBIANS																												
northwestern salamander	r.c.: 30-270/clutch, avg. 80. t.s.: not territorial.	B					2	2	1	2	1	1	1	1	1													
		F					2	1	1	2	1	1	1	1	1		2	2		2					1			2
		Rs					2	1	1	2	1	1	1	1	1		2	2		2					1			2
long-toed salamander	r.c.: 85-350/clutch. h.r.: 100 ft./adult. t.s.: not territorial. m.h.: one 0.25 acre pond/population.	B					2	2	1	2	1	1	1	1	1	2												
		F					2	2	1	2	1	1	1	1	1	2	1								1			
		Rs					2	2	1	2	1	1	1	1	1	2	1								1			
Cope's giant salamander		B						1		1	2	2																
		F						1		1	2	2																
		Rs						1		1	2	2																
Pacific giant salamander	r.c.: 70-146/clutch.	B					2	1		1	2	2	2	2		1												
		F					2	1		1	2	2	2	2		1	2			2					1		2	2
		Rs					2	1		1	2	2	2	2		1	2			2					1		2	2
Olympic salamander	r.c.: 7-16/clutch, avg. 9. t.s.: not territorial.	B					2	1		1						1											1	
		F					2	1		1						1											1	
		Rs					2	1		1						1											1	
clouded salamander	r.c.: 8-17/clutch, avg. 14. t.s.: not territorial.	B																2	2	1				2	1		2	
		F																2	2	1				2	1		2	
		Rs																2	2	1				2	1		2	
black salamander	r.c.: 7-25/clutch, avg. 15. h.r.: about 1 acre. t.s.: not territorial.	B						1		1						1									2		1	
		F						1		1						1									2		1	
		Rs						1		1						1									2		1	
California slender salamander	r.c.: 4-25/clutch, avg. 10. t.s.: not territorial.	B					2	2																	1		2	
		F					2	2																	1		2	
		Rs					2	2																	1		2	
Oregon slender salamander	r.c.: 11/clutch	B																	2					2	1		2	
		F																	2					2	1		2	
		Rs																	2					2	1		2	

Special and unique habitats [7]

B-Breeding; F-Feeding; Rs-Resting; 1 - Primary habitat; 2 - Secondary habitat.

Table 4, page C

Species 1/	Letter code 1/	Life form 2/	Versatility rating 3/	Habitat use 4/	Plant communities and stand conditions 5/: Dry hillsides	Mtn. shrubland and chaparral		Deciduous hardwood						Red alder forest				Evergreen hardwood						Conifer-hardwood forest						Mixed coniferous forest (SW Oregon)					
					1 Grass-forb	1 Grass-forb	2 Shrub	1 Grass-forb	2 Shrub	3 Open sap-pole	4 Closed sap-pole	5 Large sawtimber	6 Old growth	1 Grass-forb	2 Shrub	3 Open sap-pole	4 Closed sap-pole	1 Grass-forb	2 Shrub	3 Open sap-pole	4 Closed sap-pole	5 Large sawtimber	6 Old growth	1 Grass-forb	2 Shrub	3 Open sap-pole	4 Closed sap-pole	5 Large sawtimber	6 Old growth	1 Grass-forb	2 Shrub	3 Open sap-pole	4 Closed sap-pole	5 Large sawtimber	6 Old growth
AMPHIBIANS																																						
northwestern salamander	AMGR	2	19	B																																		
				F				1	1	2	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	1	1
				Rs				1	1	2	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	1	1
long-toed salamander	AMMA	2	19	B																																		
				F		2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2	1	1	1	2	2	2
				Rs		2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2	1	1	1	2	2	2
Cope's giant salamander	DICO	1	*	B																																		
				F																																		
				Rs																																		
Pacific giant salamander	DIEN	2	17	B																																		
				F		2	2				2	2	2			1	1				2	2	2			2	2	1	1			2	2	1	1
				Rs		2	2				2	2	2			1	1				2	2	2			2	2	1	1			2	2	1	1
Olympic salamander	RHOL	2	13	B																																		
				F													2										2	1	1			2	1	1	1
				Rs													2										2	1	1			2	1	1	1
clouded salamander	ANFE	5	22	B										1	1	1	2							1	1	1	1	2	2	1	1	1	1	2	2
				F										1	1	1	2							1	1	1	1	2	2	1	1	1	1	2	2
				Rs										1	1	1	2							1	1	1	1	2	2	1	1	1	1	2	2
black salamander	ANFL	5	18	B																				2	2	2	2	2	2	1	1	1	1	1	1
				F																				2	2	2	2	2	2	1	1	1	1	1	1
				Rs																				2	2	2	2	2	2	1	1	1	1	1	1
California slender salamander	BAAT	5	26	B																	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
				F																	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
				Rs																	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Oregon slender salamander	BAWR	5	20	B																							2	2	2						
				F																							2	2	2						
				Rs																							2	2	2						

B-Breeding; F-Feeding; Rs-Resting; 1 - Primary habitat; 2 - Secondary habitat.

Table 4, page D

		Plant communities and stand conditions [8]																								Riparian/wetland												
		Temperate coniferous forest						High temperate coniferous forest						Subalpine forest parks						Lodgepole pine (Cascades)				Shorepine (coast)				Herbaceous wetland	Hardwood and shrubby wetland						Coniferous wetland					
Species [1]	Habitat use [4]	1 Grass-forb	2 Shrub	3 Open sap-pole	4 Closed sap-pole	5 Large sawtimber	6 Old growth	1 Grass-forb	2 Shrub	3 Open sap-pole	4 Closed sap-pole	5 Large sawtimber	6 Old growth	1 Grass-forb	2 Shrub	3 Open sap-pole	4 Closed sap-pole	5 Large sawtimber	6 Old growth	1 Grass-forb	2 Shrub	3 Open sap-pole	4 Closed sap-pole	1 Grass-forb	2 Shrub	3 Open sap-pole	4 Closed sap-pole	1 Grass-forb	1 Grass-forb	2 Shrub	3 Open sap-pole	4 Closed sap-pole	5 Large sawtimber	6 Old growth	1 Grass-forb	2 Shrub	3 Open sap-pole	4 Closed sap-pole	5 Large sawtimber	6 Old growth
AMPHIBIANS																																								
northwestern salamander	B																												2	2			2	2	2	2	2	2	2	2
	F	1	1	2	2	1	1	1	1	2	2	1	1	1	1	1	2	1	1	1	1	1	2	1	1	1	2	1	2	2			2	2	1	1	2	2	1	1
	Rs	1	1	2	2	1	1	1	1	2	2	1	1	1	1	2	2	1	1	1	1	2	2	1	1	2	2	1	2	2			2	2	1	1	2	2	1	1
long-toed salamander	B																																							
	F	1	1	1	1	2	2	1	1	1	2	2	2	1	1	1	2	2	2	1	1	2	2					1	2	2	2	2	2	2	2	2	2	2	2	2
	Rs	1	1	1	1	2	2	1	1	1	2	2	2	1	1	1	2	2	2	1	1	2	2					1	2	2	2	2	2	2	2	2	2	2	2	2
Cope's giant salamander	B																																							
	F			**						**																											**			
	Rs			**						**																											**			
Pacific giant salamander	B																																							
	F			2	1	1	1			2	1	1	1				2	2	2										2	2	2	1	1	1	2	2	2	1	1	1
	Rs			2	1	1	1			2	1	1	1				2	2	2										2	2	2	1	1	1	2	2	2	1	1	1
Olympic salamander	B																												2	2	2	2	1	1	1	1	1	1	1	1
	F					1	1					1	1																2	2	2	1	1	1	2	1	1	1	1	1
	Rs					1	1					1	1																2	2	2	1	1	1	2	1	1	1	1	1
clouded salamander	B	1	1	1	1	2	2	2	2	2	2	2																												
	F	1	1	1	1	2	2	2	2	2	2	2																												
	Rs	1	1	1	1	2	2	2	2	2	2	2																												
black salamander	B																												2	2	2	2	2	2						
	F																												2	2	2	2	2	2						
	Rs																												2	2	2	2	2	2						
California slender salamander	B				1	1	1																				2		2	2	2	2	2	2	2	2	2	2	2	2
	F				1	1	1																				2		2	2	2	2	2	2	2	2	2	2	2	2
	Rs				1	1	1																				2		2	2	2	2	2	2	2	2	2	2	2	2
Oregon slender salamander	B	2	2	2	1	1	1	2	2	2	1	1	1				1	1	1																					
	F	2	2	2	1	1	1	2	2	2	1	1	1				1	1	1																					
	Rs	2	2	2	1	1	1	2	2	2	1	1	1				1	1	1																					

* Indicates a species has little orientation to plant communities or stand conditions and occurs there only if a special or unique habitat is available. Versatility ratings were not developed for these species.

** Species use these plant communities or stand conditions only if a special or unique habitat is available.

versatility ratings. Figure 7 is an example of information contained in appendix 16. These data, summarized from appendix 8, serve as the basis for calculating versatility ratings. These ratings are very general in nature and care should be used in applying them to a specific area. Where local data are available managers may want to develop their own versatility ratings.

Appendix 16 shows the number of plant communities and stand conditions used by each species for feeding and breeding. Careful examination will provide a clearer picture of the versatility of a species than will the score alone. For example, the piñon mouse (fig. 7), uses three plant communities and three stand conditions for both breeding and feeding, but may be less vulnerable to habitat manipulation than the gray-tailed vole that uses five plant communities but only one stand condition for breeding and feeding, even though both species have a versatility rating of 12.

In appendix 8 (table 4), versatility is shown by a simple numerical rating that ranges from a low of 2 for species such as the snow goose and long-billed dowitcher to a high of 42 for the coyote and deer mouse. Those species with ratings of 15 or below are considered to have low versatility, those with ratings of 16 to 28 medium versatility, while those of 29 and greater, high versatility.

The reader should note that many of the listed species having low versatility ratings, such as shorebirds and waterfowl, are essentially non-forest species adapted to special habitats (fig. 8). Versatility ratings were not calculated for species such as the Cope's giant salamander, which is strictly aquatic, and the belted kingfisher that uses an area only because of a special or unique habitat with no apparent orientation to plant communities or stand conditions. In these cases a single asterisk (*) appears in the versatility rating column.

Habitat Use The three principal animal uses of habitat are abbreviated as follows:

- B Breeding (all activity associated with reproduction and the rearing of young to the time when the young are able to survive without care).
- F Feeding
- Rs Resting (includes bedding, hiding, shelter, estivation, etc.)

Seasonal Occurrence and Activity This section of the matrix provides information concerning the period during which one can reasonably expect to find a species in a preferred habitat. Where the kind, timing, and duration of habitat use is well-documented and can be expected annually, that use is shown for breeding with a dark gray bar, feeding with a medium gray bar, and resting with a light gray bar throughout the season of occurrence.

Feeding and resting periods are the same throughout the season of occurrence except for those species that undergo torpor, hibernation, or estivation. The column opposite feeding is left blank for those periods when the animals are in torpor, hibernation or estivation.

Occasionally, a solid black bar appears opposite habitat use. Where this occurs an explanation appears in the comments section that follows seasonal occurrence. The black bar indicates one of the following:

Opposite breeding or feeding:

1. The period of breeding, hibernation, etc. is not well known, or is suspected but not verified and probably falls within the indicated period;
2. The period of hibernation, etc. varies within the region owing to differences in latitude or elevation.

Opposite resting (in the case of bats):

1. When it is not known whether they have migrated from the area or are present and hibernating;
2. The period of occurrence is not well known or varies from year to year.

Opposite breeding, feeding, and resting (in the case of birds):

1. The species is of rare or irregular occurrence;
2. It is a rare species occurring in very low numbers;
3. It is a species of very limited geographic distribution.

Comments This portion of the appendix contains a variety of key information which cannot be readily accommodated in the matrices. It shows the only information on species distribution that is provided in this publication. Any or all of the following information may appear:

1. Breeding: timing, duration, locale of any part of the reproductive cycle; specific adaptions, e.g.: delayed fertilization, implantation;
2. Specific habitat requirements;
3. Relative abundance;
4. Distribution;
5. Residence status; e.g.: winter resident, migrant;
6. Seasonal variation: in habitat uses with respect to migration, hibernation-estivation, latitude, elevation.

Table 4, Page B (Example of the second page of the appendix 8 matrix)

Species The common name is shown on each page of the matrix to aid the reader in following data across the pages.

Specific Data This section records available information concerning the reproductive capacity, territoriality, and minimum habitat requirements for the species. If no information is recorded in this column it means the species normally does not reproduce within western Oregon or Washington. When available and applicable, information is divided into four categories:

Letter code	Species common name	Life form	No. of plant communities used B	No. of plant communities used F	No. of stand conditions used B	No. of stand conditions used F
Versatility score 12						
RANCA	Cascade frog	2		6		6
CLMA	western pond turtle	3	9		3	
LOCUC	hooded merganser	14	9		3	
STOC	spotted owl	14	4	4	1	3
PIAL	white-headed woodpecker	13	3	3	3	3
SANI	black phoebe	4	3	4	2	3
HIPY	cliff swallow	4		11		1
SAOB	rock wren	4	4	4	2	2
CATME	canyon wren	4	4	4	2	2
CHGR	lark sparrow	5	3	3	3	3
PETRU	piñon mouse	4	3	3	3	3
MICAL	California vole	15	5	5	1	1
MICAN	gray-tailed vole	15	5	5	1	1
MIMO	montane vole	15	4	4	2	2
ONZI	muskrat	16	3	3	3	3
ORCU	European rabbit	15	3	3	3	3
SYFL	eastern cottontail	15	4	4	2	2
Versatility score 13						
RHOL	Olympic salamander	2		7		6
CICY	northern harrier	5	4	5	2	2
ZOAT	golden-crowned sparrow	5		10		3
CAFL	common redpoll	11		7		6
Versatility score 14						
PLDU	Dunn's salamander	3		8		6
ASTR	tailed frog	2		8		6
RABO	foothill yellow-legged frog	2		8		6
ARHE	great blue heron	12	7	3	3	1
LAEX	northern shrike	7		12		2
VIOL	red-eyed vireo	11	2	2	5	5
ORAM	mountain goat	4	3	3	4	4
THBU	Camas pocket gopher	15	5	5	2	2
DIHE	Heermann's kangaroo rat	15	5	5	2	2
ARLO	red tree vole	10	4	4	3	3
PHIN	heather vole	15	3	3	4	4

Versatility rating (mean scale): 3 6 9 12 15 18 21 24 27 30 33 36 39 — Low-122 species / Medium-154 species / High-82 species

B - Breeding. F - Feeding ■ Breeding. ▨ Feeding

Figure 7.—An example of information contained in appendix 16. The relative degree of use each species with a versatility score of 12 makes of plant communities and stand conditions for breeding and feeding.

1. *Reproductive capacity* (r.c.): shown as an average number (or range) of eggs laid or young produced by a reproducing female; embryo counts are included in some cases. Unless otherwise noted, it is assumed that species reproduce only once each year.
2. *Home range* (h.r.): defined as the area used by an individual of a species to meet biological requirements over a defined period of time;
3. *Territory size* (t.s.): defined as the area which an animal defends, usually during the breeding season, against intruders of its own species;
4. *Minimum habitat* (m.h.): given in appropriate units per pair, individual, colony or population (fig. 9).

Habitat Use All habitats with which a species has a known or probable relationship are shown to be of either primary (1) or secondary (2) importance to that species for one or more of the habitat uses (B, F, Rs). These habitat ratings are defined as follows:

1. *Primary habitat:* a preferred or optimal habitat that predictably supports the highest population density of a species; that habitat upon which a species is essentially dependent for long-term population maintenance;
2. *Secondary habitat:* a habitat that is used by a species, but is clearly less suitable than primary habitat as indicated by a lower population density or less frequent use. A habitat may be designated secondary where it is known to be used by a species but data are insufficient to clearly identify it as a primary habitat.

Figure 9.—The great blue heron typically nests in colonies of 10-50 nesting pairs but a large colony may contain over 150 pairs.

Figure 8.—Many species, such as the pika, have a low versatility rating because they are adapted primarily to special habitats.

Special and Unique Habitats Chapters 4 through 9 discuss in detail the habitat components included in this matrix. In addition, appendix 13 (an example of which is given in figure 10) shows the importance of each of these special and unique habitat components to wildlife species for breeding and feeding. Special and unique habitat components are given either primary (1) or secondary (2) rating for each species which uses them. The habitat orientation of species that are entirely dependent upon the special estuarine, riparian or wetland habitats for breeding, feeding and resting is shown only under special and unique habitats.

The terms riparian and wetland appear in two places in the matrices, as special habitats (pg B) and with reference to three plant communities (pg D). Under special habitats, "riparian and wetlands" refer to those habitats used by wildlife because of the presence of free water. Associated vegetation may or may not also be a primary habitat component.

Special and unique habitats are divided into 5 major categories that are further separated into a total of 26 types of habitat. Most of these are self-explanatory but some require definition to show how they were used in developing information for this matrix (pg B).

1. *Coastal:* habitats include saltwater (ocean), estuaries, saltwater beaches, and freshwater beaches. Species shown as breeding in saltwater (ocean) are those that use offshore rocks and islands. Species shown as using estuaries include those that use intertidal mudflats. Beaches, both salt and freshwater, were defined as an unvegetated land form along the shore of a water body, generated by waves and currents (adapted from Cowardin et al. 1979).

Total number of wildlife species using each special and unique habitat for breeding and feeding (source: appendix 8)

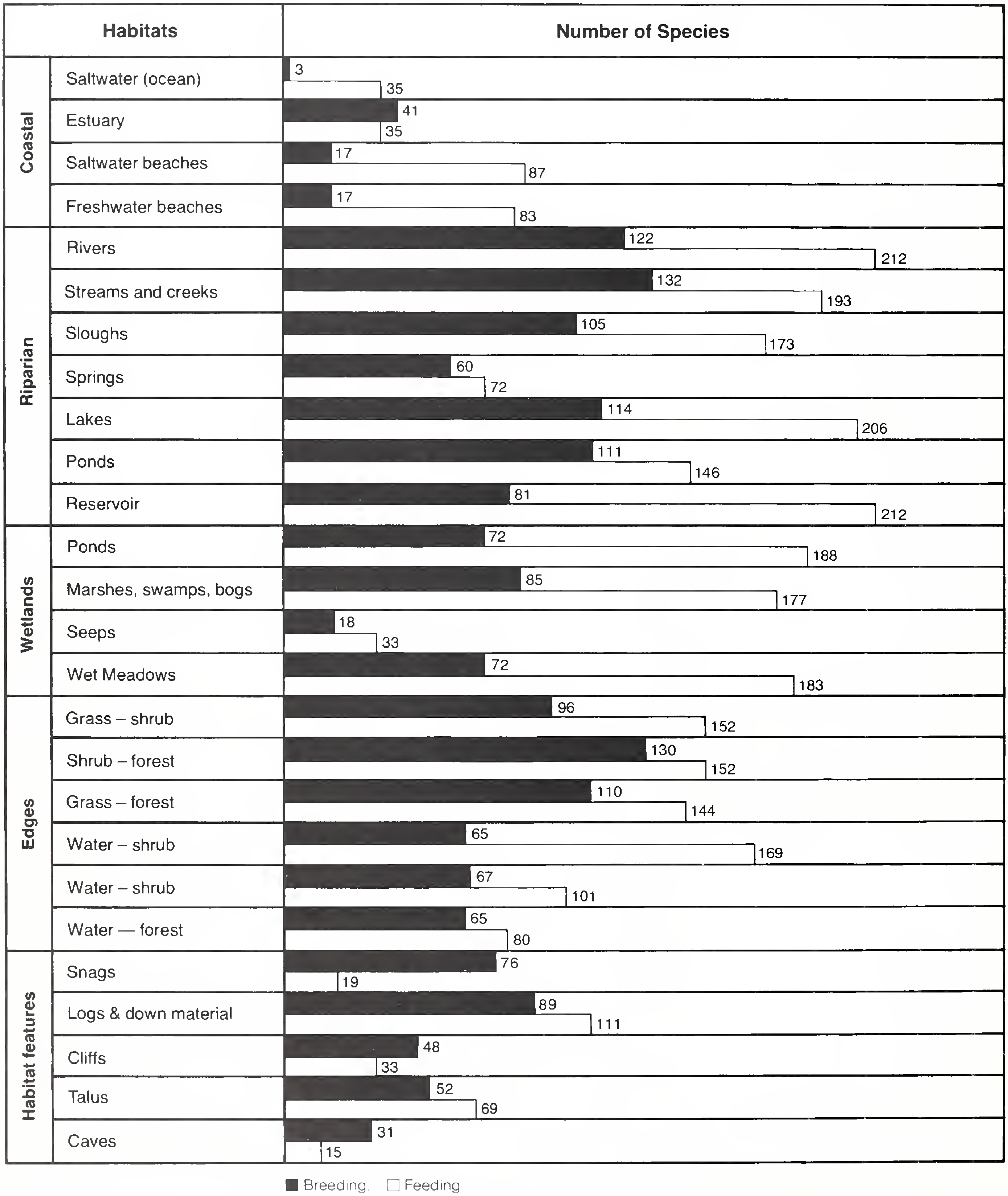
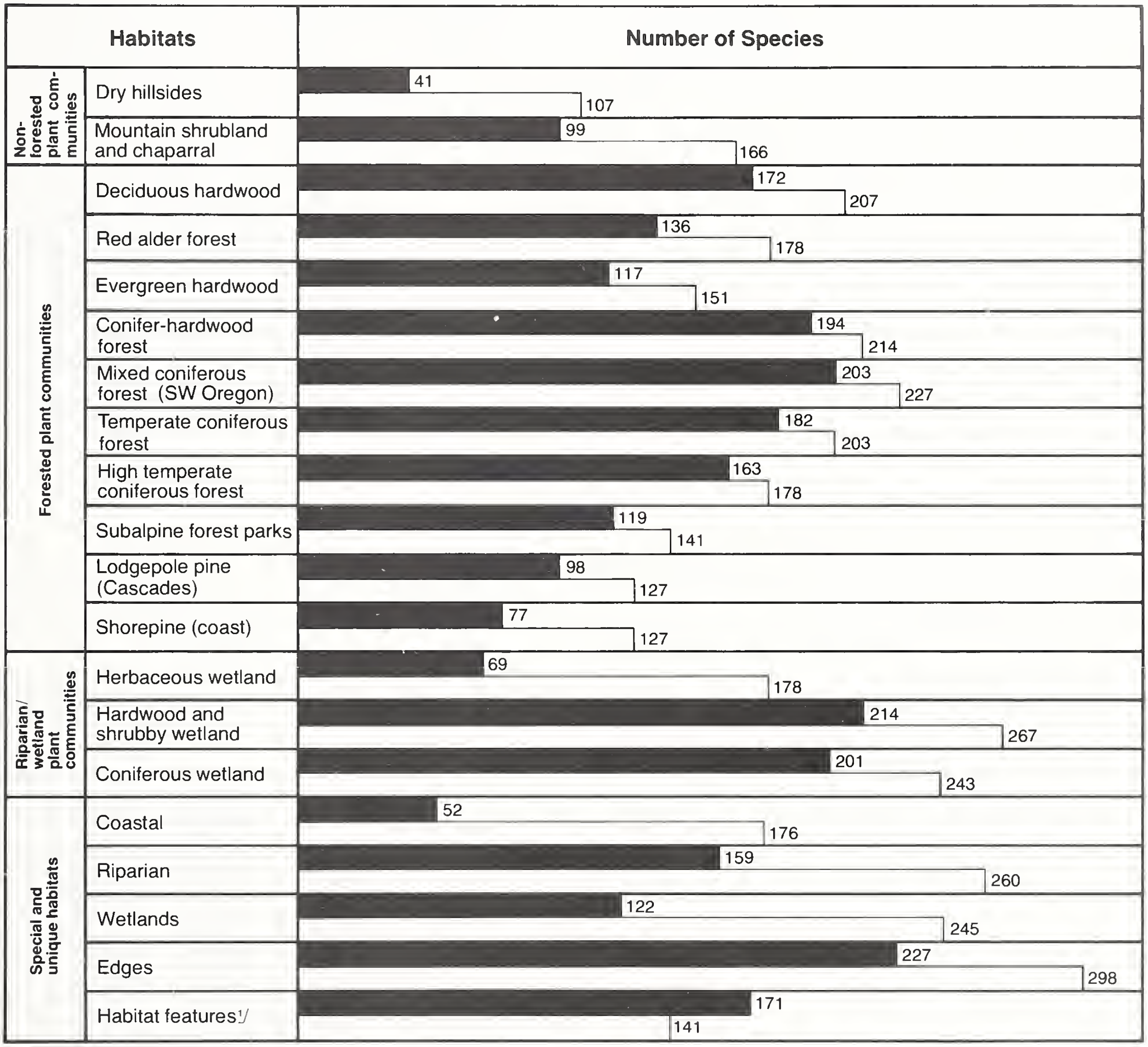


Figure 10.—An example of information contained in appendix 13.

Total number of wildife species using plant communities and special and unique habitats for breeding and feeding regardless of stand condition (source: appendix 8)



■ Breeding; □ Feeding

1/ Includes: snags, logs and down material, cliffs, talus, caves.

Figure 11.—An example of information contained in appendix 14.

2. *Riparian:* these habitats are separated into seven types that include the vegetated zone along or around most bodies of water (see chapter 4 for definitions and distinctions between riparian zones and wetlands). Species may use riparian habitats solely because of the water, solely because of the riparian vegetation, or because of both water and vegetation.

   Reservoirs included in this category typically have dramatically fluctuating water levels throughout the year. Determination of reservoir use by a species involved making a judgement whether that species might satisfy its habitat requirements in such a changing environment.

3. *Wetlands:* four types of wetland are identified. Ponds included here are distinguished from riparian ponds by their ephemeral nature, drying up sometime during the year. Marshes include both freshwater and salt marsh.

4. *Edges:* edge habitats are separated into six major types based on components creating the edge. Species may use the edge because of either one or both of these components. Chapter 6 discusses edges in detail.

5. *Habitat Features:* the habitat features included in this category of special and unique habitats are covered in detail in succeeding chapters: snags (chapter 7); logs and down material (chapter 8); and cliffs, talus, and caves (chapter 9).

Table 4, Page C & D (Example of the third and fourth pages of the appendix 8 matrix)

The last two pages of the matrix show wildlife species' orientation to the plant communities and stand conditions described in detail in chapter 2 and appendices 5 and 6. Page C contains the species common name, letter code, life form, and versatility rating as they appear on page A. Use of each plant community and stand condition for breeding, feeding, and resting is rated as primary (1) and secondary (2) for each wildlife species.

Plant Communities and Stand Conditions The 15 plant communities described in chapter 2 are listed along with their associated stand conditions. For example only one stand condition, grass-forb, occurs within the grass-forb dry hillside plant community, whereas all six stand conditions from grass-forb to old growth may be found in the deciduous hardwood plant community. The number of wildlife species using each plant community for breeding and feeding is summarized in figure 11 and for each stand condition in figure 12.

The three plant communities associated with riparian/wetland areas are identified on page D. These are distinct plant communities characterized by saturated soils and a distinctive flora (chapter 2), used by wildlife because of vegetation structure or plant composition. When free water is present these communities also may be used by species primarily oriented to the special riparian and wetland habitats.

A double asterisk (**) which may appear under any habitat use within a plant community, indicates that the wildlife species' occurrence in that community is because of orientation to a special or unique habitat and has little or no relationship to adjacent plant communities (fig. 13). Occurrence of such a species within a plant community was not used in calculating the versatility rating for that species. For example, the water shrew may be found in several other plant communities, but shows orientation only to the three riparian/wetland communities.

Figure 13.—Beaver will use riparian and wetland areas regardless of adjacent plant communities.

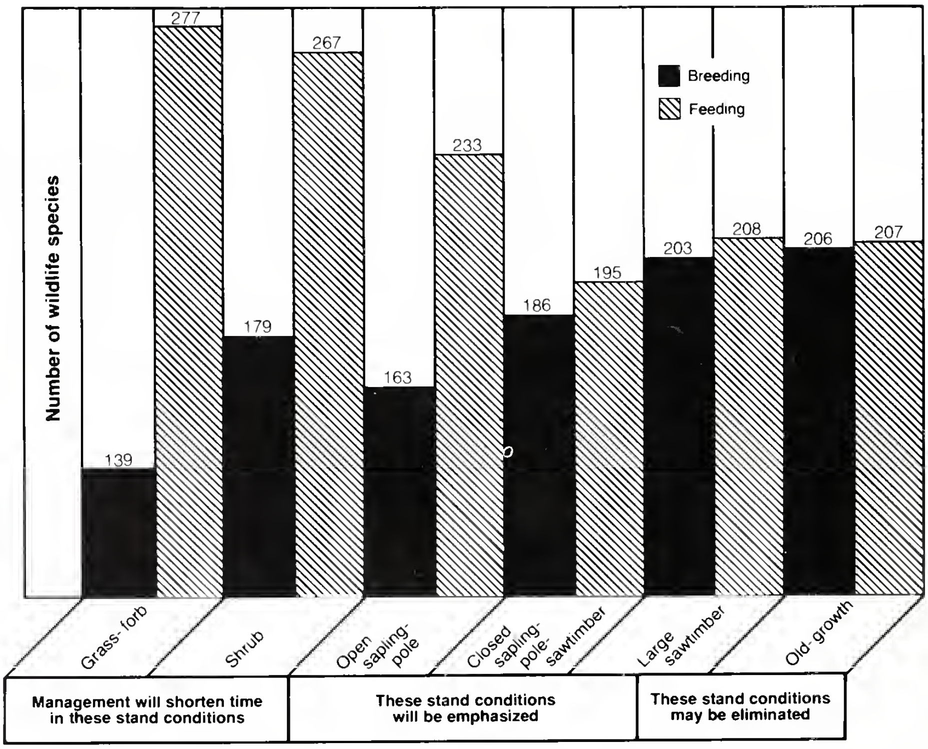


Figure 12.—Number of wildlife species oriented to each stand condition and the potential effects of intensive timber management (data summarized from appendix 15).

Using the Appendices

Appendix 8 is best used in concert by the professional wildlife biologist and forester. The degree of accuracy achieved in evaluation of a management proposal depends upon intimate knowledge of the area. An inventory of plant communities and stand conditions (chapter 2) and special and unique habitats (chapters 4, 5, 6, 7, 8, and 9) is required. A knowledge of local site conditions is essential to estimate the time required to achieve the various stand conditions. The presence or absence of wildlife species of interest must be determined by field inventories or through the use of reliable local species lists. Site specific surveys are particularly important where Federal or State classified threatened or endangered species are involved.

Table 5, taken from appendix 3, provides the most recent listing of threatened or endangered species as established by the U.S. Fish and Wildlife Service and the Oregon and Washington State Wildlife Agencies. These lists are subject to constant review and species may be added or deleted at any time. This list should only be used as a general guide and current information should be obtained from the appropriate State or Federal agency prior to implementing management programs.

Appendix 3 also includes species listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (C.I.T.E.S.) of which the United States is a party. Species on the C.I.T.E.S. list are endangered internationally or could become threatened or endangered if trade in these species is not regulated. In several cases the C.I.T.E.S. list includes entire family groups with all of the genera and species within that family, even though some species may be relatively common. An example is Falconidae that includes the endangered peregrine falcon, but this also requires listing the very common American kestrel.

Lists of species that fall into other categories such as sensitive, monitor, of state concern, or status undetermined are not included in appendix 3 (fig. 14). Such lists change even more rapidly than the threatened or endangered listing. When needed, current information should be obtained from the appropriate State wildlife agency.

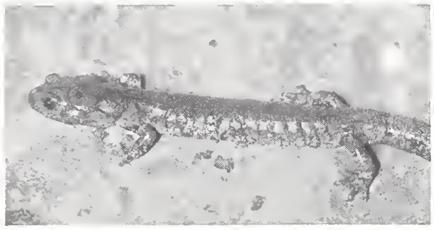


Figure 14.—The black salamander is not listed in appendix 3 but is of state concern because it is restricted to one river drainage.

When appendix 8 does not provide the desired information concerning a species, the selected references in appendix 22 should be consulted. Appendix 22 is a listing, in phylogenetic order, of all wildlife, fish, and invertebrates included in appendices 8, 11, and 12 and provides two or more selected references for each species. An example of this appendix is shown in table 6. The complete reference citation can be found in the appendix "references cited" section. The literature search on each species is not comprehensive but the references cited should serve as a starting point for acquiring more information.

Analyzing Effects of Timber Harvest

A preliminary analysis of the effects of timber harvest on wildlife can be made using figures 12 and 15. Figure 12 shows the orientation of all wildlife species in western Oregon and Washington to stand condition regardless of plant community. This can be used to give a very generalized picture of responses that can be expected from the overall wildlife community when, for example, an old-growth stand is converted to an early successional stage or stand condition.

Figure 15 (from appendix 15) gives the same type of information for the temperate coniferous forest plant community and further illustrates primary and secondary use. A comparison of wildlife species' use that can be expected as the area changes from the old-growth stand condition to the grass-forb and continuing through the closed sapling-pole-sawtimber stand conditions gives a rough evaluation of the effect of habitat manipulation. The manager should recognize, however, that this type of very general analysis is of primary value in showing relative differences in species numbers and that actual totals may differ depending on local conditions.

In most cases a more comprehensive analysis will be desired. It is suggested that the user begin by compiling from the matrices a preliminary list of all species that use the plant communities and stand conditions occurring in the area under consideration. The comments section should be consulted for distribution notes on each species during this process. Threatened or endangered species known to use the area should be designated for special consideration on the list. The comments section and the matrix showing use of special and unique habitats should then be consulted. Those species which have primary orientation to a special habitat that does not occur on the area should be eliminated from the list. Based on local knowledge, species can be added or deleted for a final list reflecting existing conditions.

A second list, consisting of species adapted to conditions which will result from the proposed action may then be compiled. A comparison of the two lists will show the total gain or loss of numbers of species and the number of species benefitted or adversely impacted by the proposal. Additional comparisons may be made to show which individual species are gained or lost and those which are unaffected by the action.

If the time required to achieve each stand condition is known, the relative species richness and individual species likely to be present may be determined for any desired point in time. This information may also be used to determine how much time must elapse before the habitat once again becomes suitable for species eliminated by the original alteration.

Table 5 — An example of information contained in appendix 3

Species requiring special consideration because of their classification by either State or Federal agencies

Computer letter code	Life form	Species common name	Federal (1) Fish & Wildl. Ser. End. Species Act	Federal (1) C.I.T.E.S. Appendix #	State (2) OR	State (2) WA
		AMPHIBIANS				
RAPR	2	spotted frog			T	
		REPTILES				
CHPI	3	painted turtle		II		
CLMA	3	western pond turtle		II		T
CHBO	5	rubber boa		II		
		BIRDS				
PEER	3	American white pelican				E
PEOC	3	brown pelican	E		E	E
ANALGA	3	Tule white-fronted goose [1]		II		
BRCALE	3	Aleutian Canada goose [1]	E	I	E	E
PAHA	12	osprey		II		
ELCA	11	black-shouldered kite		II		
HALE	12	bald eagle	T	I	T	T
CICY	5	northern harrier		II		
ACST	11	sharp-shinned hawk		II		
ACCO	11	Cooper's hawk		II		
ACGE	11	northern goshawk		II		
BULI	12	red-shouldered hawk		II		
BUSW	7	Swainson's hawk		II		
BUJA	12	red-tailed hawk		II		
BULA	5	rough-legged hawk		II		
AQCH	12	golden eagle		II		
FASP	14	American kestrel		II		
FACO	11	merlin		II		
FAPE	4	peregrine falcon	E	I	E	E
FARU	4	gyrfalcon		I		
FAME	4	prairie falcon		II		
GRCA	3	sandhill crane				E
CHAL	3	snowy plover			T	E
TYAL	14	common barn-owl		II		
OTFL	14	flammulated owl		II		
OTKE	14	western screech-owl		II		
BUVI	12	great horned owl		II		
NYSC	5	snowy owl		II		
SUUL	14	northern hawk-owl		II		
GLGN	14	northern pygmy-owl		II		
ATCU	15	burrowing owl		II		
STOC	14	spotted owl		II	T	T
STVA	14	barred owl		II		
STRNE	12	great gray owl		II		
ASOT	11	long-eared owl		II		
ASFL	5	short-eared owl		II		
AEAC	14	northern saw-whet owl		II		
		MAMMALS				
CANLU	15	gray wolf	E	II		E
URAR	15	grizzly bear	T	II		E
ENLU	1	sea otter	T	I	T	E
GUGU	5	wolverine			T	
LUCA	16	river otter		II		
FECO	4	mountain lion		II		
LYCA	5	lynx		II		
LYRU	4	bobcat		II		
ODVILE	5	Columbian white-tailed deer [1]	E		E	E

[1] subspecies

(1) Federal threatened and endangered species listings come under two classifications. The first includes those species listed by the U.S. Department of the Interior, Fish and Wildlife Service under the Endangered Species Act of 1973. The second includes those species listed in Appendices I and II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

(2) The Oregon State listing includes the federally classified threatened or endangered species along with those species that the Oregon Department of Fish and Wildlife has determined to be threatened within the state. The Washington State listing includes the federally classified threatened or endangered species along with those species that the Washington Department of Game has determined are endangered or threatened within the state.

Legend

- E Endangered - Species in danger of extinction throughout all or a significant portion of their range.
- T Threatened - Species likely to become endangered in the foreseeable future.
- I Appendix I - Species listed in this appendix are considered to be in such a precarious position that any trade would be a threat to the survival of the species.
- II Appendix II - Species listed in this appendix are not considered to be in immediate danger but continued unregulated trade could pose a threat to the species survival.

Table 6 — An example of information contained in appendix 22

Selected references for wildlife, fish and some estuarine invertebrates occurring in western Oregon and Washington

Letter code	Life form	Species common name	Selected references
VERTEBRATES			
AMPHIBIANS			
AMGR	2	northwestern salamander	Nussbaum et al. 1983, Snyder 1963, Stebbins 1954a, Taylor 1977
AMMA	2	long-toed salamander	Anderson 1967, Nussbaum et al. 1983, Stebbins 1966
DICO	1	Cope's giant salamander	Antonelli et al. 1972, Nussbaum 1970 and 1972, Stebbins 1954a
DIEN	2	Pacific giant salamander	Jones and Stokes 1980, Nussbaum et al. 1983, Stebbins 1954a
RHOL	2	Olympic salamander	Anderson 1968, Jones and Stokes 1980, Nussbaum et al. 1983, Nussbaum and Tait 1977
ANFE	5	clouded salamander	Nussbaum et al. 1983, McKenzie 1970, Stelmock and Harestad 1979
ANFL	5	black salamander	Lynch 1974, Nussbaum et al. 1983, Stebbins 1966, Storm 1974b
BAAT	5	California slender salamander	Hendrickson 1954, Nussbaum et al. 1983, Stebbins 1966
BAWR	3	Oregon slender salamander	Frieburg 1954, Nussbaum et al. 1983, Stebbins 1949, Storm 1953
ENES	5	Ensatina	Altig and Brodie 1971, Gnaedinger 1948, Jones and Stokes 1980, Nussbaum et al. 1983, Stebbins 1954b
PLDU	3	Dunn's salamander	Brodie 1970, Jones and Stokes 1980, Nussbaum et al. 1983, Stebbins 1966
PLEL	4	Del Norte salamander	Brodie 1970, Bury and Johnson 1965, Jones and Stokes 1980, Nussbaum et al. 1983, Stebbins 1966
PLLA	4	Larch Mountain salamander	Brodie 1970, Burns 1964, Nussbaum et al. 1983, Storm 1974b
PLEST	4	Siskiyou Mountains salamander	Brodie 1970 and 1971, Jones and Stokes 1980, Nussbaum et al. 1983
PLVA	3	Van Dyke's salamander	Brodie 1970, Jones and Stokes 1980, Nussbaum et al. 1983, Stebbins 1954a
PLVE	5	western redback salamander	Dumas 1956, Nussbaum et al. 1983, Peacock and Nussbaum 1973, Stebbins 1966
TAGR	2	roughskin newt	Pimentel 1952, Nussbaum et al. 1983, Stebbins 1954a, White 1977
BUBO	2	western toad	Nussbaum et al. 1983, Schonberger 1945, Stebbins 1966
HYRE	2	Pacific treefrog	Nussbaum et al. 1983, Stebbins 1954a and 1966
ASTR	2	tailed frog	Nussbaum et al. 1983, Metter 1964 and 1968, Stebbins 1954a and 1966
RAAU	2	red-legged frog	Altig and Dumas 1972, Dumas 1966, Nussbaum et al. 1983, Stebbins 1966, Storm 1960
RABO	2	foothill yellow-legged frog	Jones and Stokes 1980, Nussbaum et al. 1983, Stebbins 1954a, Zweifel 1955 and 1968
RANCA	2	Cascade frog	Altig and Dumas 1971, Briggs and Storm 1970, Dumas 1966, Nussbaum et al. 1983
RACAT	1	bullfrog	Nussbaum et al. 1983, Stebbins 1954a and 1966
RAPR	2	spotted frog	Dumas 1966, Nussbaum et al. 1983, Stebbins 1966, Storm 1974b

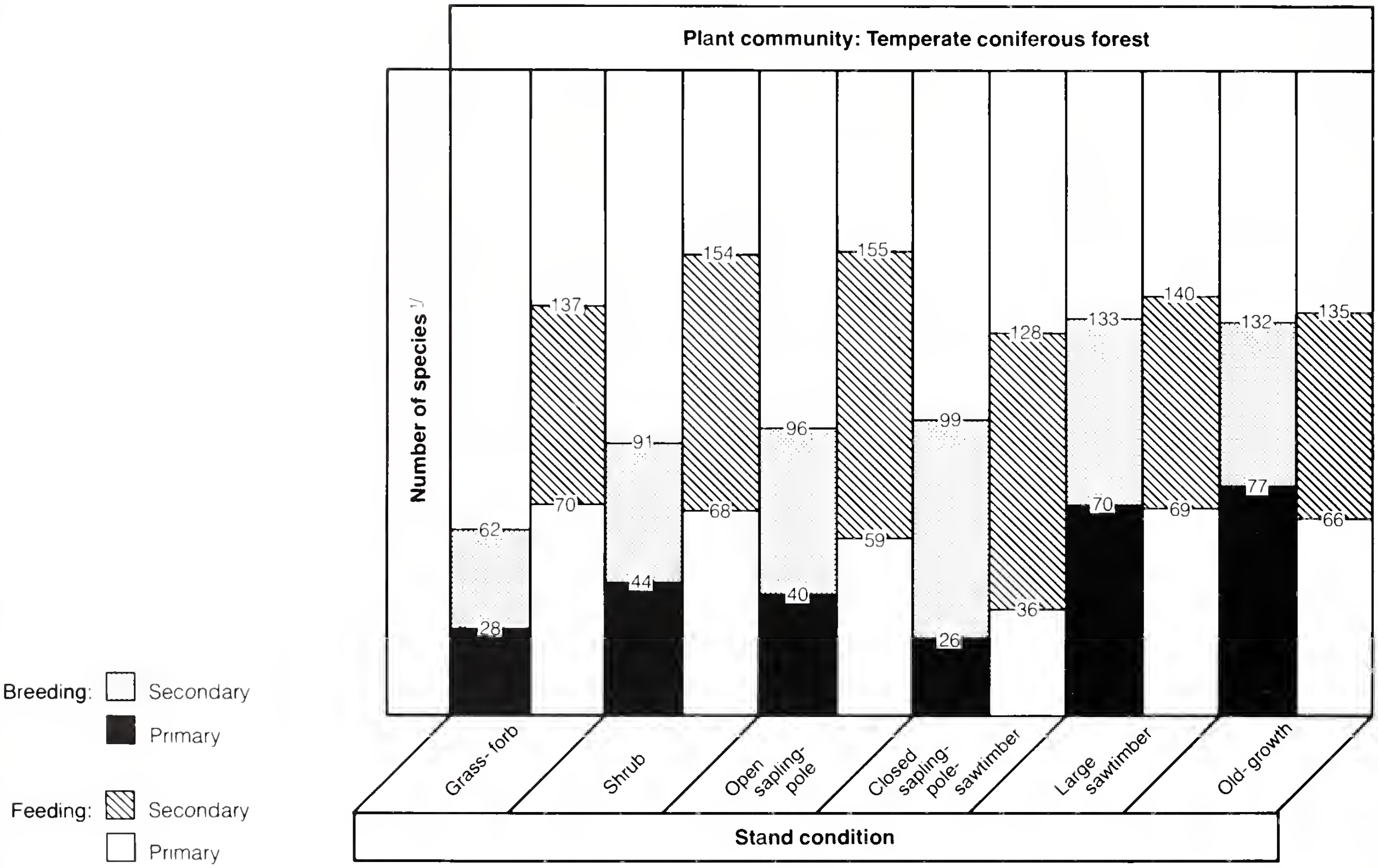


Figure 15.—An example of information contained in appendix 15; number of wildlife species using each stand condition in the temperate coniferous forest plant community. The lower number in each column represents primary use only; the upper number a combination of both primary and secondary.

Old-Growth Harvest Example

The process described in the preceding paragraphs is illustrated in table 7; it shows how information given in appendix 8 can be used to evaluate the effects of timber harvest on wildlife. For purposes of this example, the action takes place on federal lands where a clearcut is planned in a contiguous stand of old-growth Douglas-fir timber, in the temperate coniferous forest plant community. A perennial stream forms one boundary of the unit. Snags are present and will be felled. Subsequent harvests will take place when the regenerating stand reaches the later stages of the closed sapling-pole-sawtimber stand condition. The following conditions apply to the example shown in table 7:

- *Species list, versatility rating:* Six representatives of three vetebrate classes showing widely differing versatility are chosen to represent the complete species list a user would assemble from appendix 8 or other sources. It is assumed that the presence of each species has been confirmed.

- *Threatened, endangered, and other specially listed species:* The presence of the spotted owl, classified as threatened by the States of Washington and Oregon, requires a determination that the proposed harvest is consistent with guidelines for management of the species.

- *Special and unique habitats:* An inventory is assumed. Primary orientation to these habitats is shown and the habitat used by each species is identified. The probable effect of the proposed action on the habitat used by each species is indicated.

- *Presence or absence:* Habitat use in each stand condition following harvest is shown for each species. It culminates in the small sawtimber stand in which the next harvest will occur.

- *Effect and management considerations:* Impacts and needs should become obvious at this point in the analysis. Appropriate chapters in this publication and the selected references (appendix 22) should be consulted for detailed management considerations.

Table 7 —Effects of clearcut timber harvest in old-growth temperate coniferous forest on six selected wildlife species

Species	Versatility rating	Threatened (T) or endangered (E)	Primary use	Special and unique habitats: Habitat used	Special and unique habitats: Altered, Removed, Created	Presence – absence by stand condition and by use: Grass-forb	Shrub	Open sapling-pole	Closed sapling-pole-sawtimber	Large sawtimber	Old growth	Effect: Negative	Effect: Positive	Management considerations
tailed frog	Low		Yes	Riparian logs	Removed	F	F	F	F	These stands eliminated	These stands eliminated	Severe		Buffer streams, provide logs
Ensatina	High		Yes	Riparian logs	Removed			B F	B F			Severe		Buffer streams, provide logs
Sharp-shinned hawk	High		No	N/A	N/A			B F	B F			Moderate		Stagger harvest of adjacent harvest units
spotted owl	Low	State "T"	No	Natural cavities	Removed				F			Severe		Consider long rotations (see chapters 12 & 14)
flying squirrel	Med.		Yes	Snags	Removed				B F			Severe		Leave snags (see chapter 7)
black-tailed deer	High		Yes	Riparian edges	Edges created	B F	B F	B F	B F				Moderate	Disperse cutting units (see chapter 11)

B - Breeding F - Feeding

A comparison of species of very different versatility, such as the black-tailed deer and spotted owl, is revealing. The spotted owl would not use the area until the closed sapling-pole-sawtimber stand condition is achieved. Because spotted owls use this stand condition only for feeding, the species would not occur there unless breeding habitat was present nearby. Black-tailed deer, on the other hand, would benefit from creating additional edge, a special habitat to which it is primarily oriented. Because it is adapted to all stand conditions which will follow the harvest, it can be expected to persist on the site continuously through time at varying population levels.

A more refined analysis would determine and project diversity according to percentage of different stand conditions and special habitats available to wildlife over time. The approach outlined above may be used to eliminate or mitigate adverse impacts on selected species or groups of species, as well as to predict results of existing management strategies.

References Cited

Cowardin, L. M.; Carter, V.; Golet, F. C.; LaRoe, E. T. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. Washington, DC: U.S. Fish and Wildlife Service; 1979. 103p.

Thomas, J. W., tech. ed. Wildlife habitats in managed forests: The Blue Mountains of Oregon and Washington. Agric. Hand. 553. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979. 512 p.

4

Riparian Zones and Freshwater Wetlands

Art L. Oakley
Jim A. Collins
Larry B. Everson
David A. Heller
Jack C. Howerton
Robert E. Vincent

Table of Contents

Introduction

Riparian zones and freshwater wetlands are among the most heavily used wildlife habitats occurring in forest lands of western Oregon and Washington. Biologists have recognized this for years, but only recently has the significance of riparian and wetland productivity been well quantified by research studies. Of the references cited in this chapter, the majority have been published since 1970. Results of ongoing research are expected to further substantiate and expand our knowledge of wildlife use in these habitats.

Riparian Zones

Webster's New World Dictionary, 2d. college edition defines riparian as: "of, adjacent to, or living on the bank of a river or, sometimes, of a lake, pond, etc." The riparian zones discussed in this chapter occur along rivers, streams, lakes, reservoirs, ponds, springs, and sometimes tidewater (fig. 1). They have high water tables because of their close proximity to aquatic ecosystems, certain soil characteristics, and some vegetation that requires free (unbound) water or conditions that are more moist than normal. These zones are transitional between aquatic and upland zones. As such they contain elements of both aquatic and terrestrial ecosystems (fig. 2).

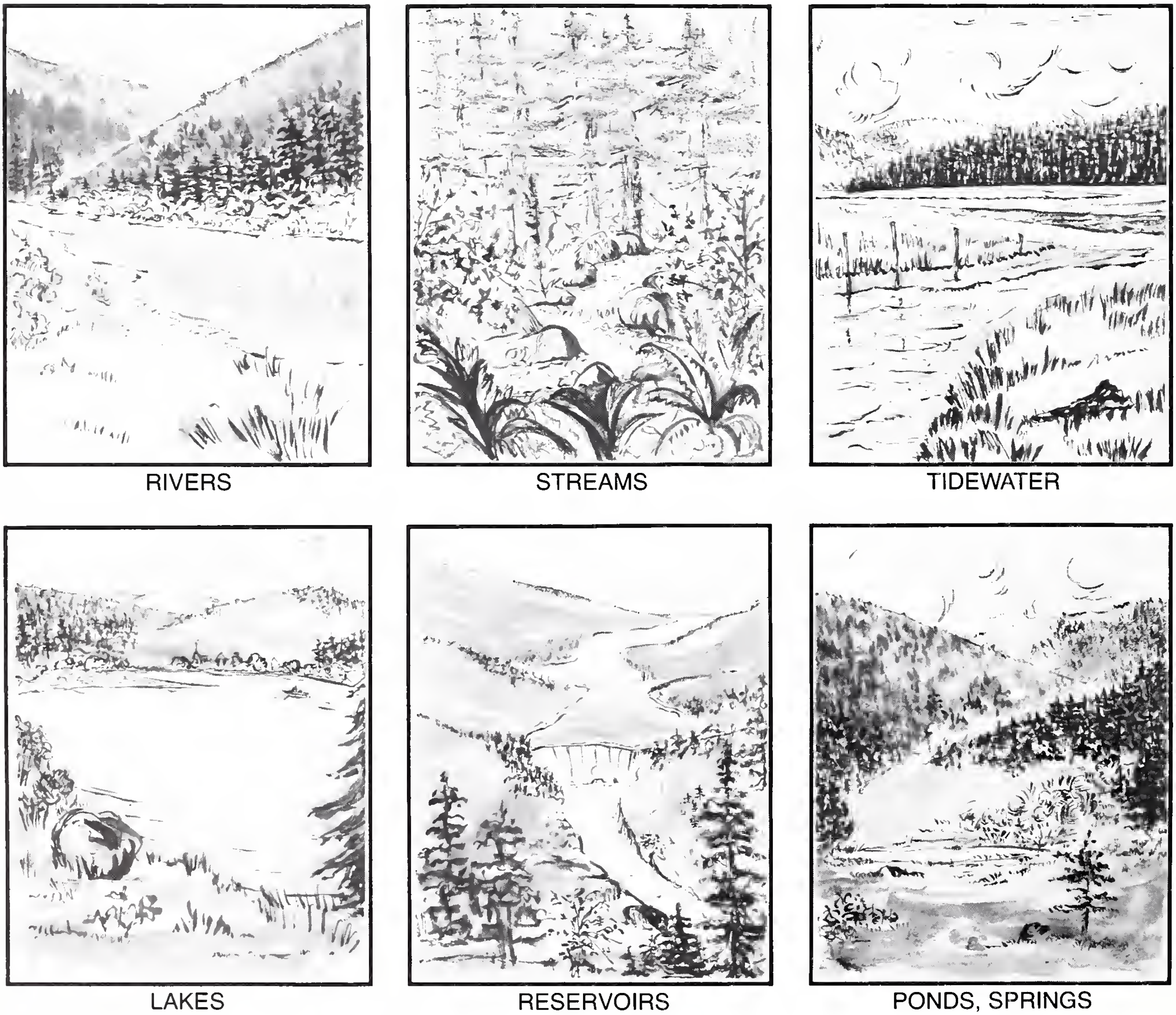


Figure 1.—Aquatic habitats common to western Oregon and Washington that have associated riparian vegetation influenced by the type of water.

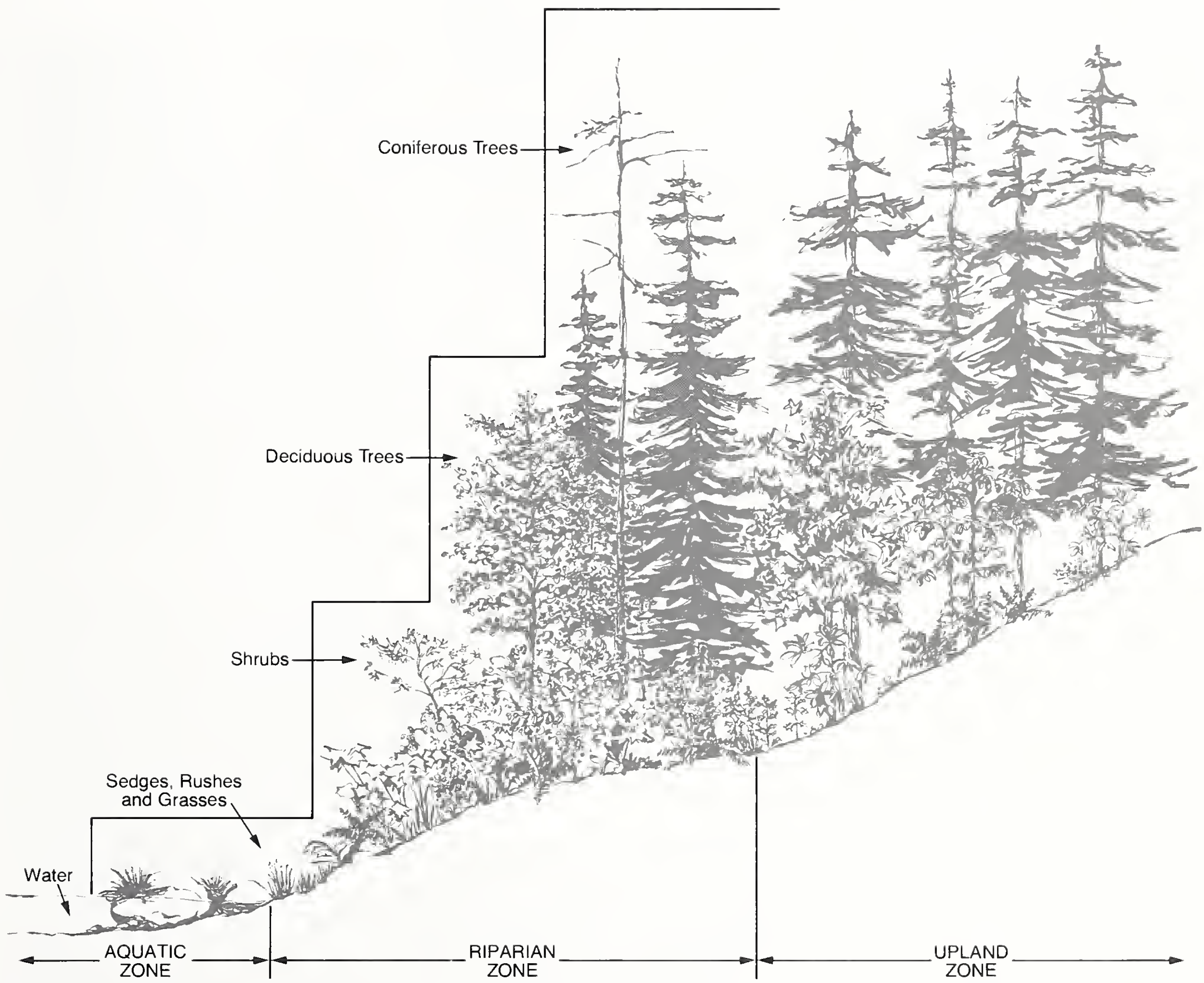


Figure 2.—Riparian zones have vegetation that requires large amounts of free or unbound water and are transitional between aquatic and upland zones.

In the Pacific Northwest, most riparian zones occur along streams and rivers. Such habitats can extend through entire drainage systems from the smallest intermittent headwater streams to the largest rivers (fig. 3). The terms "riparian zones" and "riparian areas"are used interchangeably in this chapter, but by strict ecological definition, they may not be the same in all instances.

Vegetation found in riparian zones usually includes hydrophytes (skunk cabbage, coltsfoot, lady-fern, sedges, devil's club, water-parsley, stink currant, willows, etc.) and species which also occur in drier sites (red alder, salmonberry, vine maple, bigleaf maple, black cottonwood, Sitka spruce, western redcedar, California-laurel, Douglas-fir, etc.) (Brown et al. 1980, Campbell and Franklin 1979, Franklin and Dyrness 1973, Maser et al. 1981, Minore and Smith 1971, Proctor et al. 1980, Walters et al. 1980). Riparian vegetation west of the Cascade Range in Oregon and Washington usually consists of herbaceous ground cover, understory shrubs and overstory trees (Swanson et at. 1981). The edge between riparian and upland zones is usually identified by a change in plant composition, relative plant abundance, and the end of high soil moisture.

Any of the plant communities described in chapter 2 can occur in riparian zones. There is great variability in both the size and vegetative complexity of riparian zones because of the many combinations possible between physical and biological characteristics. These characteristics include stream gradient, elevation, soil, aspect, topography, water quantity and quality, type of stream bottom, and plant community (Campbell and Franklin 1979, Odum 1971, Swanson et al. 1981, Walters et al. 1980). Numerous habitats and niches usually occur within any riparian zone because of these varying conditions.

Figure 3.—Riparian habitat conditions vary with the location and size of the stream. There also is considerable difference in their importance to wildlife. Larger, more productive riparian zones are usually found along medium-sized or larger streams.

The natural succession of vegetative types following major disturbances such as floods, fires or logging, determines the kinds of vegetation occurring in a riparian zone at any given time. Pioneer species include willows on gravel bars and red alder on mineral soil (Campbell and Franklin 1979). Stream deposition and erosion influence the topographical features of floodplains and have pronounced effects on the vegetative composition and habitat conditions of riparian zones (Brinson et al. 1981).

Riparian zones of western Oregon and Washington possess the same characteristics as those listed by Thomas et al. (1979a). They occupy only a small part of the overall area but are a critical source of diversity within the forest ecosystem. They create distinct habitat zones within the drier surrounding areas. In addition, riparian zones are elongated in shape with very high edge-to-area ratios (Odum 1979). They therefore possess a high degree of connection with other habitat types and function as effective transport systems for water, soil, plant seeds, and nutrients to downstream areas (Ewel 1979) (fig. 4). They also serve as important travel routes for the movement or dispersal of many wildlife species.

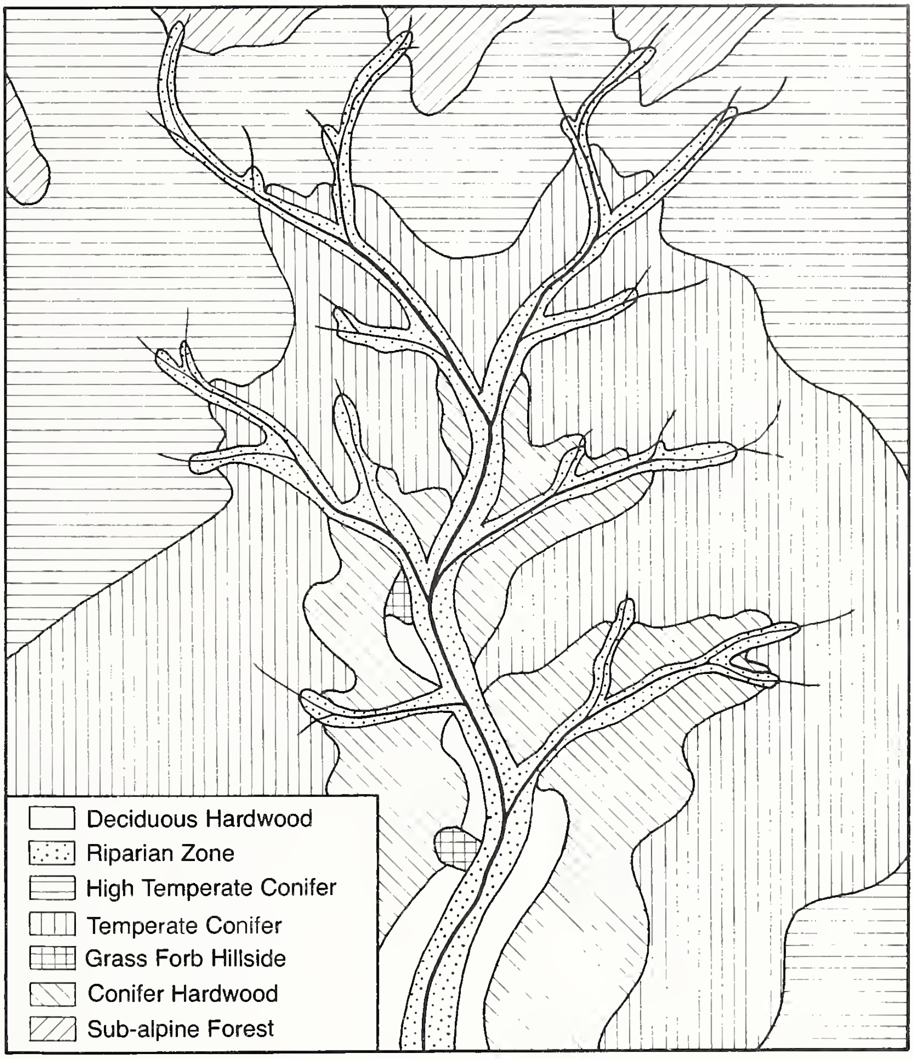


Figure 4.—Riparian zones along streams and rivers function as connectors between habitat types. They are important migration routes for some wildlife species and serve as travel routes for numerous species because of the presence of water, food, and cover.

Freshwater Wetlands

Wetlands are areas that are permanently or intermittently flooded. The water table is normally at or near the surface, or the land is covered by shallow water not exceeding 6.6 feet in depth at low water. Hydric soils occur and vegetation is composed of floating or submergent aquatics and emergent hydrophytes which require saturated or seasonally saturated soil conditions for growth and reproduction. Examples of wetland plants include yellow water-lily, cat-tail, rushes, skunk cabbage, sedges, cotton-grass, willow, alder, black cottonwood, and western redcedar (Cowardin et al. 1979, Franklin and Dyrness 1973, Proctor et al. 1980). In certain areas, however, vegetation may be completely lacking as on flats where drastic fluctuations in water levels or wave action prevent growth of hydrophytes.

Wetland habitats include freshwater marshes, swamps, bogs, seeps, wet meadows, and shallow ponds (fig. 5). Not included are lakes and reservoirs over 20 acres in surface area with less than 30 percent areal vegetative cover or deeper than 6.6 feet in the deepest part of the basin at low water. These two types of water bodies are considered deep-water habitats, as recently classified by the U.S Fish and Wildlife Service (Cowardin et al. 1979).

In summary, wetland and riparian habitats are characterized by high diversity (numbers of species), density, and productivity of both plant and animal species. There are continuous interactions among the aquatic, riparian and adjacent upland zones through exchanges of energy, nutrients, and species (Cummins 1980, Franklin et al. 1981, Meehan et al. 1977, Odum 1979, Swanson et al. 1981). The direct role of riparian areas in affecting the productivity of aquatic habitats for salmonid fishes is discussed in detail in chapter 10.

Figure 5.—Small ponds, marshes, wet meadows, and bogs are types of freshwater wetlands that add diversity to the forest lands of western Oregon and Washington and provide crucial habitats for aquatic and semi-aquatic species.

Importance of Riparian Zones and Wetlands

Riparian zones and wetlands provide some of the most important wildlife habitat in forestlands of western Oregon and Washington. Wildlife use is generally greater than in other habitats because the major life requirements for many species are present. Aquatic and amphibious species are normally found only in these habitats (fig. 6). Water is the habitat for aquatic life forms, including many species of invertebrates, fish, amphibians, reptiles, birds, and mammals. Vertebrates that either feed or reproduce in water are directly dependent on wetlands or riparian areas and adjacent aquatic areas. Many other species, although not completely dependent on riparian or wetland habitats, tend to use them to a greater degree than upland areas.

Riparian zones are important for many other types of land use. Highly productive timber sites frequently occur along streams and around wetlands or lakes. Livestock utilize vegetation in riparian zones more heavily than in other areas because they concentrate here for water, shade, and succulent forage. Riparian zones are used for road locations, particularly in mountainous, rugged terrain. Rock and gravel for building roads have been taken from streambeds and their banks as well as from floodplains. Mining has direct and indirect impacts on riparian areas. Recreationists concentrate their use in wetland and riparian areas where scenic values are high. Riparian zones are preferred for recreational developments such as campgrounds and summer home sites. Because of these conflicting uses, riparian zones are recognized as critical areas in multiple use planning.

Figure 6.—Many wildlife species require riparian or freshwater wetland habitat to survive. Many others show a preference for these habitats even though their survival may not be dependent on riparian or freshwater wetland habitat.

Riparian zones are more numerous than wetlands in forested areas west of the summit of the Cascade Range and are of much greater significance to forest management. Riparian zones are of paramount concern as wildlife habitat for the following reasons:

1. Most riparian zones contain water, cover, and food—the three critical habitat components.
2. Riparian zones have a greater diversity of plant composition and structure than uplands. There are more internal edges and strata in a short distance due to understory shrubs, deciduous trees, and coniferous trees than in adjacent upslope forest stands (fig. 7). Where riparian zones are dominated by deciduous vegetation, they provide one type of habitat in late fall and winter after leaf fall, and a different type of habitat during late spring and summer when in full leaf.
3. The elongated shape of most riparian zones maximizes edge effect with the surrounding forest as well as with water. This produces high edge-to-area ratios, and creates productive habitats for many species (see chapter 6).
4. Riparian zones have different microclimates from surrounding coniferous forests due to increased humidity, a higher rate of transpiration, and greater air movement. These conditions are preferred by some species during hot weather.
5. Riparian zones are natural migration routes and serve as travel corridors for many wildlife species such as ruffed grouse, bats, deer, beaver, mink, and raccoons, to name just a few. Cover, water, and sometimes food are available for birds and animals when they are dispersing from their original habitats in search of new territories. Strips of old-growth forest left along streams also serve as "connectors" for wildlife to move between otherwise isolated stands of old growth (Franklin et al. 1981) (fig. 4).
6. Productive fish habitats and good water quality depend on well-developed vegetative communities in riparian zones. Self-sustaining riparian forests stabilize streambanks and adjacent slopes and provide food and recruitment of large woody debris to streams (see chapter 10).

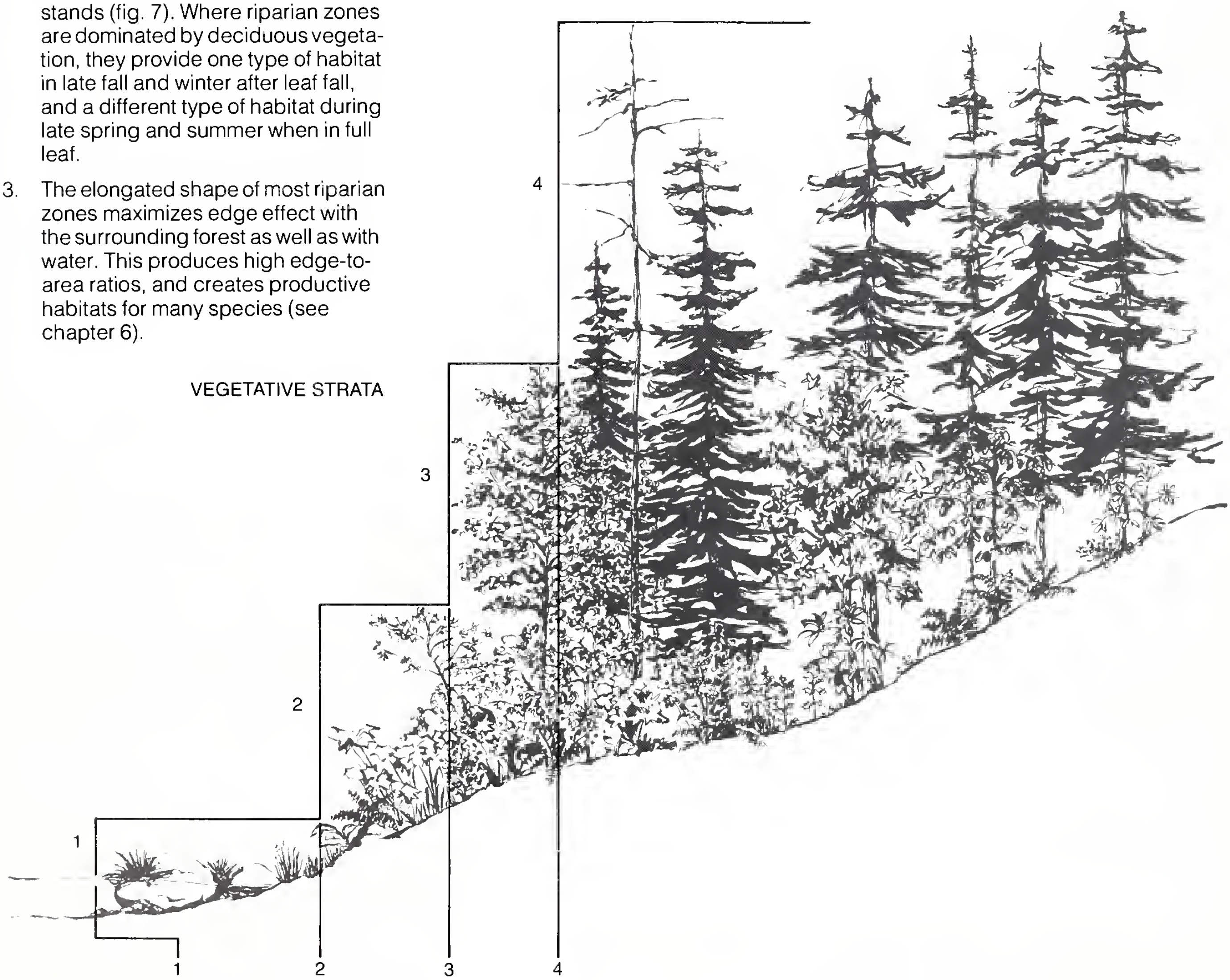


Figure 7.—Riparian zones often have a high number of strata and edges in a relatively small area. This produces habitat for a greater number of species because of the diversity of plants which create numerous "habitat niches."

Major Elements of Riparian Zones and Wetlands

There are many types of riparian zones and wetlands in the Northwest. It is important to be able to identify physical and biological differences in order to properly understand and manage them. It is also necessary to understand the natural processes which cause changes in these habitats. A brief discussion of the major elements of riparian zones and wetlands should facilitate such an understanding. By observing each element, it is possible to draw general conclusions regarding the nature of an area and its management needs. In all cases, field reconnaissance,operational experience, and professional judgment are fundamental to evaluating and managing riparian zones and wetlands.

A wide variety of factors are frequently mentioned to define the character and function of riparian zones and wetlands (Brown et al. 1979; Campbell and Franklin 1979; Collotzi 1978; Cowardin et al. 1979; Odum 1971). The following five important elements are discussed:

1. Topography
2. Vegetation
3. Surface water (including flowing water)
4. Soil
5. Local climate

These elements should provide a basic framework for analyzing and understanding the management needs of riparian zones and wetlands. Additional elements can be added to this list depending on individual needs and the type of planned management activity. Each element is discussed as it relates to defining the quantity, quality, and function of riparian zones and wetlands.

Topography

Topography as used here refers to the "lay of the land" within and adjacent to riparian zones and wetlands. It affects a number of physical (e.g., erosion, deposition, hydroperiod, soil formation) and biological (e.g., plant and animal communities, animal use) characteristics. The topography of the surrounding landscape can be used to stratify riparian zones and wetlands having similar structural and functional characteristics (Brown et al. 1979). Collotzi (1978) and Heller and Maxwell (1980) classified potential riparian resource production based heavily on topographic features including entrenchment, floodplain width, and stream gradient.

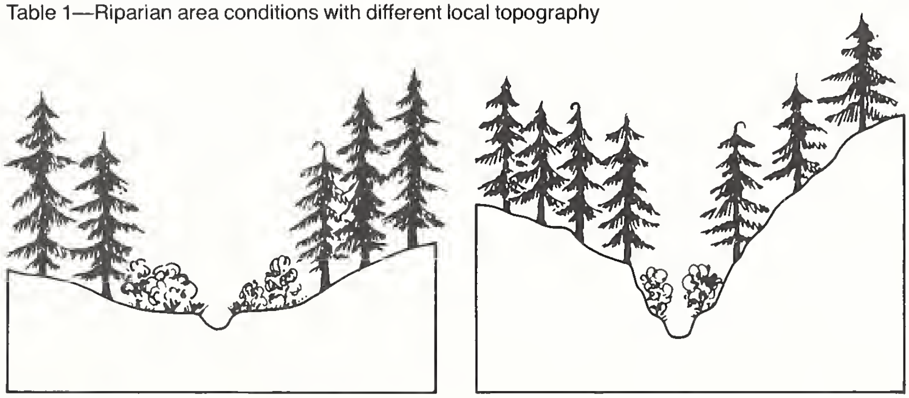
Topography often determines the space available for the development of riparian or wetland plant communities. It is a primary indicator of the type, frequency, and magnitude of erosion/deposition processes occurring in an area. It may have a major influence on local climate, particularly sunlight, temperature, and wind. Topography may strongly influence the occurrence and relative effect of various upslope disturbances (windthrown trees, landsliding, etc.) on riparian zones or wetlands. It determines the capability of the riparian zone for many types of uses.

A comparison of selected characteristics of two riparian zones having substantially different surrounding topography is shown in table 1.

Vegetation

Vegetation has numerous functions in riparian zones and wetlands. It defines the number and type of wildlife habitats present. Vegetation stabilizes soil and streambanks and provides nutrients to the soil. On small to moderate-sized streams, leaves and debris (litter) provide the primary source of energy for the aquatic system (Franklin et al. 1981). Large dead and down trees store nutrients, provide seed beds for various tree species, provide habitat for various wildlife and, when incorporated into streams, control channel structure and stability (Franklin et al. 1981, Swanson et al. 1976). Both the physical and biological structure of riparian vegetation also has a strong influence on the growth, density and biomass of salmonids in adjacent streams (Martin et al. 1981) (chapter 10).

Table 1—Riparian area conditions with different local topography



A. Broad, Open Area

- Local Slopes: 30%
- Location: Well developed floodplains. Also includes lakes, wetlands (marshes, bogs, ponds, wet meadows).
- Dominant process: Deposition.
- Soils: Deep and often fine textured.
- Sunlight: Year-round.
- Winds: Relatively open to disturbance.
- Vegetation and structure: Localized variations in soil type, moisture, and disturbance often create high diversity.

B. Narrow, Entrenched Area

- Local Slopes: 60%, often 80%
- Location: Poorly developed floodplains. Also includes small glacial or landslide lakes, small wetlands around springs or seeps.
- Dominant process: Active erosion and transport.
- Soils: Often shallow and coarse textured.
- Sunlight: Often partially blocked during winter months or long periods of the day.
- Winds: Relatively sheltered.
- Vegetation and structure: Often limited.

The composition of vegetation refers to both the number and abundance of various plant species. Composition is controlled by many factors, including topography, substrate, and stream gradient (Campbell and Franklin 1979, Walters, et al. 1980). Composition also may be influenced by adjacent stands of timber, particularly old growth, through shading and competition (Campbell and Franklin 1979, Franklin et al. 1981).

The structure of vegetation relates to how available space is occupied by different species and sizes of plants. Habitat diversity is controlled by the stratification or structure of vegetation, both vertically and horizontally (Kelly et al. 1975) (fig. 7). In general, it appears that the greatest structural diversity in riparian areas is provided by old-growth stands of timber (Campbell and Franklin 1979, Franklin et al. 1981).

An important aspect of vegetative composition and structure is the potential for both short-term (seasonal) and long-term (successional) change. Seasonal changes, due to the emergence and die-off of annual plants, may cause small scale changes in composition and structure. On a larger scale, the leafing out and subsequent fall of leaves from deciduous vegetation cause major seasonal variations in the habitat conditions of a wetland or riparian zone. Seasonal changes can produce considerable differences in the amount of food and cover available for wildlife use.

Natural succession changes the structure and composition of vegetation over longer periods of time (Meehan et al. 1977). Succession is frequently the result of disturbance such as floods and fires which may involve large areas but occur infrequently. Streambank erosion, channel deposition, and blowdown or mortality of individual trees are small scale disturbances which occur frequently. The patterns of vegetative succession primarily depend on the frequency of disturbance and the substrate of a given area (Campbell and Franklin 1979). These patterns play a dominant role in controlling the diversity of vegetation and, hence, the number and type of niches provided for various wildlife species. Activities of man, like road construction or logging operations, can cause small to large-scale alterations in vegetative communities of riparian zones and wetlands.

Surface Water

The presence of surface water during all or part of the year is a common characteristic of riparian zones and wetlands. The character of the surface water—whether standing (lakes, ponds, marshes, etc.) or running (streams and rivers), and whether perennial or intermittent—plays an important role in the function of these areas. The character of surface water directly controls the type of aquatic habitat, the composition and diversity of vegetation, and its potential use by wildlife, livestock, and man. In wetlands the duration of surface water and its chemistry influence the decomposition process in organic soils (Cowardin et al. 1979).

Hydroperiod (the frequency of flooding in a riparian zone or wetland), is described as the key external factor controlling vegetative composition and productivity (Odum 1979). Hydroperiod may determine the relative resistance of an area to change; a shorter hydroperiod usually means a higher likelihood of change (Ewel 1979). In maintaining or improving riparian zones and wetlands, maintenance of natural flow regimes are important. Extremes (stagnant water, abrasive flooding) or major changes (damming, diversion, fire, logging, etc.) are likely to lower the productivity of an area (Ewel 1979, Odum 1979).

Soils

Soils provide the substrate which supports much of the biological activity of a riparian zone or wetland. They are an expression of the previously mentioned components acting over time. Parent material for riparian soils is usually water-carried sediments whose characteristics depend on the geology and hydrology of the drainage basin. Wetlands, which typically have no flowing water to transport sediments, usually have parent material characteristic of the local geology at a site (Brown et al. 1979).

Important parameters in the classification of wetland soils include soil organic content, drainage, texture, and nutrient content (Brown et al. 1979). Frequently, wetland soils have high percentages (20+ percent) of incompletely decomposed vegetation and are referred to as organic soils (Buckman and Brady 1972). These organic materials are largely provided by overlying or adjacent wetland vegetation.

Texture influences permeability or drainage of soils and their relative susceptibility to erosion. Fine-textured soils found on broad floodplains or wetlands generally are highly productive with good moisture-holding capacities. They are susceptible, however, to compaction as well as surface and/or stream erosion unless streambanks are well vegetated. Coarse-textured soils, often found on narrow floodplains and glacial scour lakes, are characterized by relatively lower productivity and poor moisture-holding capacity. They are less susceptible to erosion and compaction than fine-textured soils.

Combinations of these two divergent types of soil textures may be found in any given riparian zone or wetland. This variability in soil character results in a variety of plant habitats (Odum 1979).

Local Climate

Weather exerts a decided influence on most physical and biological processes of riparian zones and wetlands. It controls the frequency and magnitude of major disturbances such as floods, fires, and wind storms. Climate directly influences the character of soils by controlling physical and chemical reactions and various biological processes (Buol et al. 1973). Regional climatic factors interact with local conditions (topography, elevation, aspect, soil factors, and characteristics of surface water) to determine the types of vegetation in a given wetland or riparian area (Walters et al. 1980).

Wildlife Use of Riparian Zones and Wetlands

Major components of climate are moisture and temperature. These factors interact to determine potential plant and animal populations. Temperature is more limiting where moisture conditions are extreme, while moisture plays a more dominant role where there are extremes in temperature (Odum 1979). Because of abundant water and vegetation, extremes in temperature and/or moisture are ameliorated to a greater degree in riparian zones and wetlands than in nearby upland areas.

In the mountains of the Pacific Northwest, climate is strongly affected by elevation. Although riparian and wetland plant communities show change with elevation, these changes are less pronounced than in drier regions (Walters et al. 1980). Latitude also has an influence on climate between southwestern Oregon and northwestern Washington.

Habitat Functions

Wildlife use riparian zones and wetlands disproportionately more than other areas. Odum (1979) stated that the density and diversity of wildlife are greater in riparian zones and wetlands than in other habitats. Stevens et al. (1977) showed that the effect of riparian zones is not limited to wildlife directly dependent on these zones but that populations in adjacent areas are strongly influenced by the presence and quality of the riparian community. Activities that alter or destroy riparian or wetland habitats will have serious impacts on wildlife because of the large variety of species that use these habitats (Carothers 1977).

Wildlife require food, water, cover, and space which includes areas to feed, breed, rear young, hide, and rest as well as habitats that provide protection from extremes of heat and cold (thermal cover). The density, diversity, and structure of vegetation, combined with the landforms found in riparian zones and wetlands, tends to provide these requirements for a great many wildlife species. More habitat niches are provided in riparian zones and wetlands than in any other type of habitat. Use of these areas is a classic example of the "edge effect" (Odum 1979). Many species not directly dependent on these areas for their basic life functions, utilize them as preferred habitat during certain seasons of the year or as travel corridors in moving from one location to another (Taber 1976, Tabor 1976).

Of the 414 western Oregon and Washington wildlife species covered in appendix 8, 359 use riparian zones or wetlands during some season(s) or part(s) of their life cycles (table 2). Of these, 318 species use one or more of the three plant communitites directly associated with riparian zones and wetlands. Another 41 species use riparian zones or wetlands as special or unique habitats but do not use any of their associated plant communities. These include species such as the shorebirds, gulls, some waterfowl, and harbor seals that use the waters or shorelines of riparian and wetland areas for feeding or resting but do not venture far from the water's edge.

Some species such as the spotted frog, beaver, muskrat, and many waterfowl species are totally dependent upon riparian or wetland areas. Species such as the roughskin newt, ruffed grouse, willow flycatcher, striped skunk, and dusky-footed woodrat may live in other habitats but reach maximum population densities in riparian or wetland areas. Still other species occupy a broad array of habitats including riparian zones and wetlands but at sometime during their life cycle spend a significant amount of time in these areas. Examples of such species are Pacific tree frog, western toad, Cooper's hawk, yellow warbler, bobcat, and Roosevelt elk. Many species with significant economic importance, such as most of the furbearers, are products of riparian zones and wetlands.

Habitat functions that attract wildlife to riparian zones and wetlands are discussed in the following sections.

Table 2—Number of wildlife species using riparian zone or freshwater wetland habitats [1]

Class	Number of westside wildlife species	Number of species using riparian or wetland plant communities	Number of species using riparian zones or wetlands as a specialized habitat but not using plant communities	Total number of species using riparian zones or wetlands
Amphibians & Reptiles	44	35	2	37
Birds	267	192	38	230
Mammals	103	91	1	92
Total	414	318	41	359

[1] Data from appendix 8.

Foraging and Watering

Riparian zones and wetlands provide an abundance and variety of quality food for wildlife. Because of the diversity in vegetation and landforms, many vertical levels (strata) are available for foraging. Seed-eating birds and mammals feed in canopies of tree and shrub layers as well as on seed-producing groundcover. The black-capped chickadee, song sparrow,

and western harvest mouse are examples of seed-eating species found in riparian zones.

Insect eaters such as shrews, bats, flycatchers, swallows, woodpeckers, warblers, salamanders, turtles and snakes find food sources at different levels in riparian communities. Wildlife that feed primarily on vegetation also find an abundant source of quality food in riparian and wetland habitats, e.g. deer, elk, grouse, rabbits, and voles. Beaver and muskrat are species that are totally dependent on food from riparian and wetland vegetation for survival. Other species like the raccoon can survive outside riparian zones and wetlands but reach their maximum densities in this type of habitat.

There are also those wildlife that feed on fish, crayfish and other aquatic or amphibious organisms. Belted kingfisher, American dipper, great blue heron, river otter, mink, Pacific giant salamander, western aquatic garter snake and Pacific water shrew are examples of wildlife that may not survive without food provided by these habitats.

Predators such as hawks, owls, eagles and coyotes are attracted to riparian and wetland habitats by the abundance of prey species. Bald eagles and ospreys are particularly dependent upon riparian and wetland habitats.

Free water is also an extremely important habitat component of riparian zones and wetlands, particularly in summer. Band-tailed pigeons use mineral springs for their water, and young upland game birds need water daily.

Breeding and Rearing

Diverse riparian and wetland areas provide a wide variety of habitats where wildlife can breed and rear young. Fawning and calving areas are usually near water where good quality food and cover are available. Trees, shrubs, and ground cover are used by a great variety of songbirds, shorebirds, wading birds, raptors, and waterfowl for nesting and rearing young. Dippers, for instance, nest on cliffs or banks in moss watered by spray from waterfalls and riffles. Great blue herons nest in large trees of the riparian zones. Wood ducks that require cavities for nesting will use dead or dying trees found in riparian zones and wetlands. Red-winged blackbirds and marsh wrens are examples of species that use marsh vegetation for nesting. Waterfowl nest in a variety of habitats, some on floating nests in the water, some in riparian vegetation, and still others in upland vegetation adjacent to riparian zones and wetlands. All waterfowl species, however, use riparian zones and wetlands for brooding.

Most bald eagles nest in trees or snags along shores of large lakes and streams, perch in snags and trees, and feed on fish, waterfowl, and shorebirds. Ospreys also nest atop trees or snags along waterways and lakes, and feed on fish. The peregrine falcon , a cliff nester, feeds almost exclusively on birds, many of which are associated with riparian zones and wetlands.

Banks, ground cover, hollow logs and trees in the riparian zone provide denning habitat for many small to medium-sized mammals. Beaver, muskrat, raccoon, and Pacific water shrew are examples of mammals that use these habitats in riparian zones or wetlands. Although roughskin newts and western toads frequent forest habitats, they must have ponds, lakes or slow-moving streams for breeding.

Rearing habitat is extremely critical for most species. Rearing areas must be near nesting, fawning, and other areas where young are produced. Species that nest, den or otherwise produce young in riparian zones and wetlands also rear their young there. There must be an abundant supply of food and hiding cover for young, as well as for adults. Feeding areas and hiding cover must be close together to allow ready access between them.

Hiding and Resting

Hiding and resting cover is an essential habitat element for wildlife. Dense vegetation, complex landforms, and abundant water found in riparian zones and wetlands provide this important requirement. Burrows, dens, hollow logs and trees, cavities in logs and trees, and dense foliage are essential for many species of mammals, birds, and other wildlife.

Beaver and muskrat rest and take refuge from enemies in dens with underwater entrances. Rabbits and hares hide and rest in burrows, rocks, litter or dense underbrush. Large mammals often hide in thickets of riparian shrubs and trees. Many small mammals burrow or create "runs" under or through this dense vegetation which allows protection from predators. Frogs and turtles rest on emergent vegetation, logs, or floating material in the water and also hide in water and emergent vegetation.

Waterfowl, such as mallard ducks and Canada geese, use sheltered areas along streams for loafing and protection during severe weather. Riparian and wetland vegetation also provides perches for species such as bald eagle, osprey, belted kingfisher, and willow flycatcher. Since riparian zones and wetlands normally support denser vegetation than adjacent upland areas, they provide hiding and resting cover for many wildlife species that are not otherwise dependent on this type of habitat.

Large mammals, furbearers, and predators use riparian zones as travel corridors to and from summer and winter ranges and between feeding, resting, hiding, breeding, brooding, and rearing habitats. Riparian zones and wetlands are also used as stop-over areas by migrating songbirds.

Thermal Cover

The local climate of riparian zones and wetlands is strongly influenced by location, topography, presence of water, and the amount and diversity of vegetation. Extremes in climate are moderated by these factors. Vegetation that ameliorates temperature extremes is referred to as "thermal cover". These areas are often cooler in summer and warmer in winter. In many areas during winter, particularly in severe winters, riparian zones and wetlands may be the only areas where snow does not render the habitat unsuitable to large and medium-sized mammals and to some forest birds. In summer, when humidity is low and temperature very high, these areas provide a cooler, moister climate for wildlife than surrounding upland habitats. Large mammals such as Roosevelt elk and blacktailed deer use riparian zones to migrate seasonally between summer and winter habitats.

Management Considerations

The high value of riparian zones and wetlands must be considered when making management decisions that affect these habitats. The density and diversity of vegetation, combined with a variety of landforms, create edges and microclimates that provide an almost infinite number of habitat niches for wildlife. Heavy use of these habitats by wildlife illustrates their importance.

Riparian zones and wetlands are by nature especially susceptible to natural and man-caused disturbances. Riparian communities in particular, being long and narrow and having extensive interface with both aquatic and terrestrial systems, are highly vulnerable to impact from major upslope events. The cumulative effects of activities in tributary watersheds on riparian zones and wetlands located at lower elevations is an important management consideration.

Human activities are often concentrated in riparian zones and wetlands. Water bodies provide life necessities: hydropower, minerals, diverse and abundant biota, and productive floodplains for forestry and agriculture. In addition, larger rivers are transportation routes where recreation and lifestyle are enhanced by the plant diversity and proximity to water. People are attracted to riparian zones and wetlands for many of the same reasons as are wildlife. Competition between man and wildlife is intense for this limited area.

Forest managers and planners should recognize that riparian zones and wetlands are (1) vulnerable to severe alterations because of their relatively small size and location, and (2) sensitive due to their distinct vegetative communities and microclimates. Because of the interface between aquatic and terrestrial communities, managers should consider the impacts of activities that occur in riparian zones and wetlands to both on-site and downstream communities. For these reasons, riparian zones and wetlands along with their associated water bodies should be managed as one unit within a watershed. Fishery and wildlife biologists, hydrologists, and soil scientists should be consulted when management activities are planned that could affect these important habitats.

Natural Events

Riparian zones are geologically unstable environments, characterized by erosion and deposition (Leopold et al. 1964). Swanson (1980) reviewed the relationships among the ecological time scale, biota, and geomorphic processes. He found that vertical channel erosion lowers the water table, accelerates slope erosion, and may cause adjustment in the profile of the entire drainage network. Horizontal channel erosion (meanders), common on floodplains, undercuts riparian vegetation and erodes soil only to deposit it downstream. Deposition forms meadows, wetlands, and channel bars where plant succession commences again (Morisawa 1968). Smaller wetlands are often ephemeral habitats where a slight amount of either deposition or erosion may change their character. Natural disturbance can be reduced and recovery hastened through careful management (Cairns 1980). Some natural disturbance is desirable, however, and helps to create diversity and may aid in achieving management objectives.

Floods accelerate erosion and deposition, inundate streamside vegetation, and deform, kill, scar, or uproot riparian vegetation. Often, mass soil movements, debris torrents, and organic debris dams are associated with floods (Ketcheson and Froehlich 1978, Swanson and Lienkaemper 1978, Swanson et al. 1976, Swanston 1978 and 1980). These events destroy existing riparian vegetation, but can also form new riparian zones or wetlands as stream profiles are changed. Large organic debris, which develops naturally under old-growth forest conditions, is a major factor in controlling the biological and physical features of smaller forest streams (Bilby and Likens 1980, Bryant 1980, Heede 1972), and in providing an important habitat component in riparian areas (Franklin et al. 1981).

Other catastrophic events such as wildfire (Lyon et al. 1978) (fig. 8), windstorms (Ruth and Yoder 1953), or volcanic eruptions may damage the biota severely (Swanston 1980). The total

Figure 8.—Many riparian areas have been severely impacted by fires and subsequent salvage logging operations as shown by this 1967 photo.

destruction of riparian habitat by massive mud flows resulting from the eruption of Mount St. Helens in May, 1980, is illustrated by figure 9. These large scale natural catastrophies occur infrequently. Over time, affected areas recover as communities become re-established, but time becomes more important as competitive uses intensify the frequency or magnitude of disturbance.

Wildlife populations, if unregulated, can create significant impacts on localized areas of riparian and wetland habitat. High beaver populations increase the frequency of bank burrowing and dams, attendant sediment deposition, and consumption or destruction of riparian vegetation. Raising of the water table and flooding change habitats from lotic to lentic conditions (Gard 1961, Hair et al. 1979). Many of these newly formed lentic habitats are small wetlands. Downslope soil movement along heavily used game trails and overbrowsing by large wild ungulates can have effects in localized areas. Burrowing animals, such as mountain beaver, can alter natural soil-water movement patterns (Swanson 1980). Colony nesting birds sometimes cause excessive damage to vegetation (Carey and Sanderson 1981, Jackman 1974).

Figure 9.—Aerial view of the South Fork of the Toutle River, June 4, 1980, showing the complete inundation of the floodplain and riparian zone following the eruption of Mount St. Helens.

Timber Management

Complete removal of riparian vegetation (clearcutting to the water's edge) severely impacts not only the habitat of many riparian wildlife species but water quality and fish habitat as well (fig. 10). Oregon and Washington have adopted forest practice rules and regulations concerning the removal of streamside vegetation (State of Oregon 1980a, State of Washington 1982). Federal agencies with forest management responsibilities also have policies and guidelines governing timber harvest in riparian zones and wetlands (see chapter 10). Compliance with these regulations and guidelines, if properly applied, should provide significant protection for wildlife habitats in riparian zones and wetlands.

Maintaining vegetative buffers or leave strips is an important stream riparian management practice designed to protect water quality and fish and wildlife resources during logging operations (Erman et al. 1977, Federal Water Pollution Control Administration 1970, Franklin et al. 1981, Moring 1975, U.S. Environmental Protection Agency 1973 and 1976) (fig. 11). These buffer zones are not a panacea in all instances (Streetby 1971), and windthrow can be a problem (Franklin et al. 1981, Steinblums 1977). Well designed leave strips, however, have generally been successful in achieving management objectives for water quality and fish habitat and should be equally effective in wildlife habitat management. Effective leavestrip width and composition will vary with stream order, topography, vegetation, management objectives, and land use (Lantz 1971b, U.S. Environmental Protection Agency 1976). Lantz (1971a) discussed how leave strips eliminate or minimize three of the four major stream-habitat changes associated with logging, i.e., water temperature, sediments, and dissolved oxygen in surface and subgravel waters. A leave strip not only reduces impact on streams from upslope land use activities, but also maintains the diversity of the long, narrow riparian zone relatively intact.

If harvest of forest products in a riparian zone is planned, careful evaluation must be given to impacts on fish and wildlife habitat. Selective or shelterwood cutting will have less impact than clearcutting on canopy density and solar radiation, which in turn affects stream-water tem-

perature and microhabitat (Brown 1970, and 1974, Thomas et al. 1979a) (fig. 10). After on-site inspection and consultation with wildlife and fishery biologists and the establishment of management objectives, it may be possible to selectively harvest some trees from the riparian zone without creating undesirable changes in habitat conditions. Important factors to consider in this decision are that the narrower the riparian zone or the greater the number of trees harvested, the more susceptible the area becomes to loss of habitat function and productivity. Detailed recommendations, pictures, and guidelines for logging practices that limit direct and indirect impacts on riparian zones are included in several publications (Federal Water Pollution Control Administration, 1970, Lantz 1971b, Moring 1975).

Research concerning the effects of logging on stream flows has demonstrated that changes in annual stream flows are minimal in larger watersheds where timber harvesting is done in small, well-spaced clearcuts. In small headwater watersheds, however, studies have shown that road building, clearcutting, and other activities associated with timber harvesting may result in (1) significant increases in annual water yield and summer low flows, (2) increases in fall peak flows and small winter peak flows, and (3) increases in large, major winter peak flows if more than five percent of the watershed has been compacted (Harr 1976, Harr and Krygier 1972, Harr and McCorison 1979, Harr et al. 1979, Harris 1973, Rothacher 1970 and 1973). Variations do occur and much depends on the amount of watershed disturbed, the harvest system used and the time since the activities were conducted (Dyrness 1967, Harr 1980).

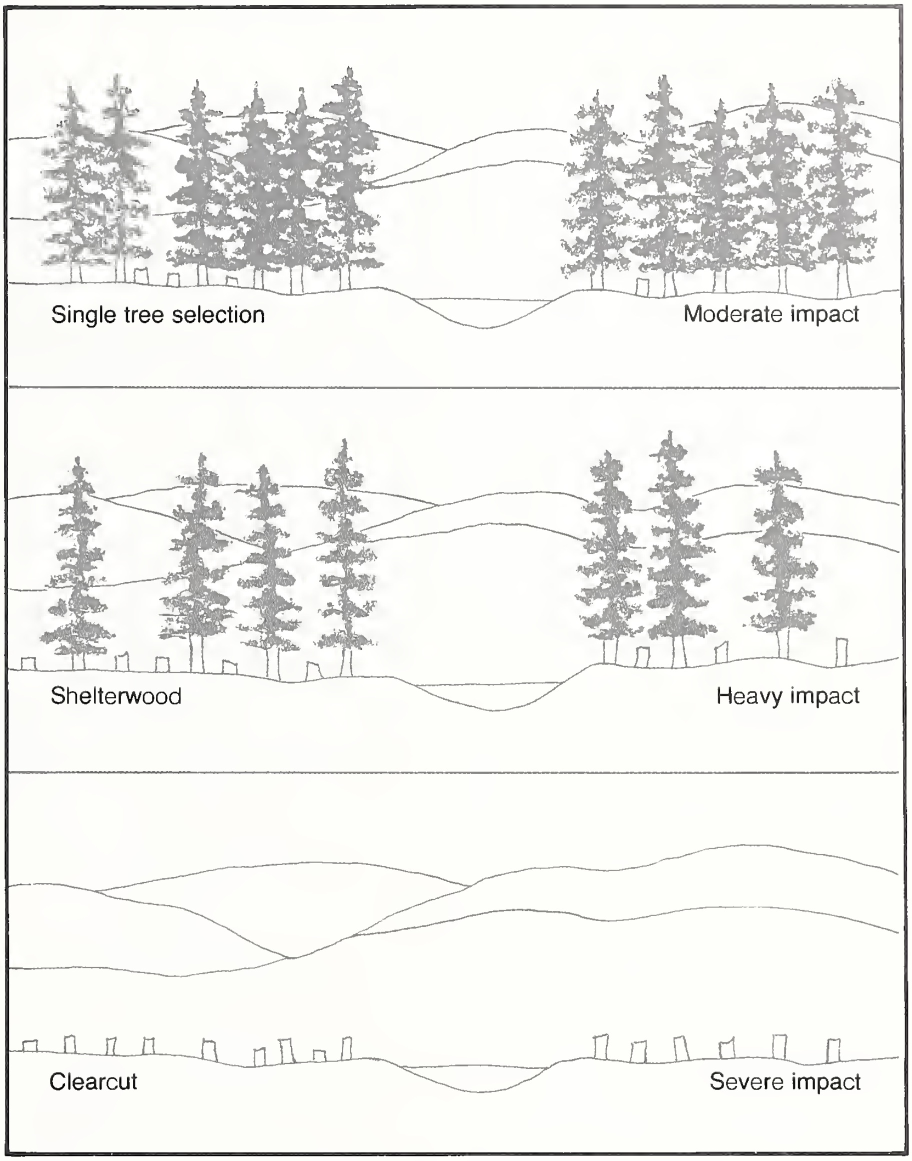


Figure 10.—Environmental impacts should be carefully evaluated when timber is cut in riparian zones.

Figure 11.—Habitat diversity in riparian zones is maintained by leaving conifers as well as hardwoods in vegetative buffers adjacent to streams. These trees, when they die, may become snags providing habitat for cavity users (see chapter 7) or when they fall to the ground they provide habitat for many other species (see chapter 8) as well as providing structure in stream channels (see chapter 10).

Onsite damage to stream channels and adjacent riparian habitats in small watersheds can occur due to increases in peak winter flows after logging. Downstream impacts in streams of larger basins may be lessened by vegetative conditions in uncut areas. Except on highly disturbed and compacted areas, infiltration capacity and erodibility can return to prelogged conditions within three to six years (Johnson and Beschta 1980).

If wildlife habitat is to be protected, timber harvest should be carried out in a manner that will maintain normal water movement and minimize adverse impacts from floods on stream channels and riparian zones. Because clearcuts and road construction can greatly accelerate the natural rate of debris avalanches and debris torrents (Swanson and Lienkaemper 1978, Swanston 1980), practices to minimize these events should be encouraged in order to reduce undesirable alterations of established riparian communities (fig. 12).

Figure 12.—Debris torrents in stream channels carry tons of soil, rocks, boulders, and vegetative material downstream causing longlasting adverse impacts on the productivity of riparian and aquatic habitats.

To maintain desirable habitat conditions, natural, stable organic material in the form of large debris in stream channels and large down logs in riparian areas should be left undisturbed during logging operations (Franklin et al. 1981, Swanson et al. 1976) (fig. 13). It should be recognized, however, that forest residues remaining after timber harvest can exert both favorable and unfavorable influences on animal populations (Dimock 1974). If natural logs are scarce, some large and small down material resulting from logging operations should be left in the riparian zones. Because logging may add significantly to the total amount of debris (Froehlich 1971), the amount and location of logging debris left in riparian areas should be carefully determined to reduce the risk of subsequent large debris dams, debris avalanches or debris torrents. Large conifers retained in riparian zones would ensure a source of dead and down woody material for future habitat needs.

The type of yarding system chosen by forest managers can do much to minimize the impact of tree harvest on

Figure 13.—Trees that fall across streams are used as bridges by many wildlife species until they decay and fall into the stream where they add structure to the stream channel.

riparian zones. Use of full cable suspension, ballooon, or helicopter transport removes trees with almost no disturbance of soil or vegetation (U.S. Environmental Protection Agency 1973 and 1976). Uphill felling reduces breakage and keeps felled trees out of the riparian area (Burwell 1971). Parallel felling can also be effective in preventing damage to riparian vegetation where steep side slopes occur. Natural amounts of small organic debris are essential to the aquatic food chain (Cummins 1974 and 1980) and large organic debris helps small stream channels dissipate energy and store sediments (Swanson and Lienkaemper 1978, Swanson et al. 1976). Excessive accumulations of small debris in streams, however, may deplete oxygen levels (Moring 1975).

Forest roads, if constructed near streams or across wetlands, reduce the productivity of riparian and wetland habitats for many wildlife species (fig. 14). Recommendations for the proper location of roads and landings, drainage structures, road surfaces, and road construction and maintenance are discussed by Greene (1950), Lantz (1971b), Larse (1971), U.S. Environmental Protection Agency (1975), and Yee and Roelofs (1980). In contrast to past practices, many new forest roads are being located away from riparian zones and along benches or ridgelines. In order to reduce soil movement on steep hillsides, instead of side-casting, excavated material is end-hauled by truck to stable waste areas.

Many streams are currently paralleled by roads. Managers should take this into consideration if a new streamside road is proposed. The amount of riparian habitat already seriously impacted should be determined and this information carefully weighed in making a final decision on the road location. More than any other management activity, road construction has the most critical and lasting impact on riparian zones (Thomas et al. 1979a).

Improperly located, constructed, or maintained roads may initiate or accelerate slope failure (Yee and Roelofs 1980) which in turn triggers debris torrents. Stream crossings should be at right angles to disturb the minimum amount of riparian vegetation. Bridges and culvert installations should be of the proper size and design to limit channel erosion and debris accumulations and provide unrestricted passage for migrating fish (see chapter 10).

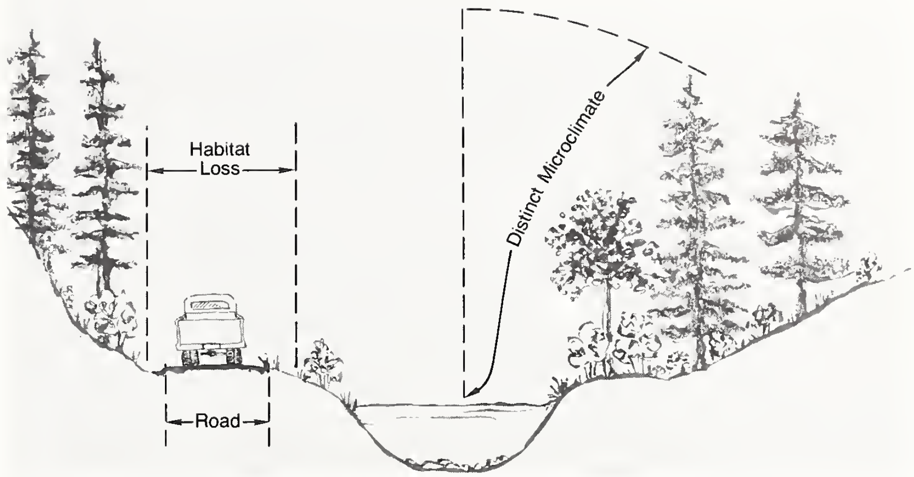


Figure 14.—Road construction in riparian zones reduces their productivity as wildlife habitat. Roads alter vegetative structure, change microclimate, reduce the size of riparian zones, impact water quality in the aquatic zone, eliminate habitat and result in disturbance of wildlife.

Common silvicultural applications of fertilizers and pesticides (herbicides, insecticides, and rodenticides) usually will not seriously impact riparian zones and wetlands if these areas are not treated, and accepted precautions are followed to prevent excessive drift into downslope areas (Miller and Fight 1979, USDA Forest Service 1974, U.S. Environmental Protection Agency 1973 and 1977). These precautions include no-treatment areas or buffers of sufficient width based on site-specific conditions, and restrictions on aerial applications to times when winds are less than five mph, etc. Healthy riparian communities help prevent adverse impacts on water quality by natural filtering of sediments containing pesticides before they reach the stream. Where steep slopes are highly dissected by stream channels, it may be difficult to keep aerial applications of herbicides out of riparian zones and streams. In such cases, the "no spray" alternative should be given serious consideration.

Livestock Grazing

Although livestock grazing in riparian zones and wetlands is not as widespread west of the Cascade Range as it is in the more arid eastside areas, effects can be significant in certain locations. Most livestock grazing on forested lands occurs in southwestern Oregon where weather is relatively hot and water is often in short supply during the summer months. The greatest likelihood for adverse impacts on riparian zones from livestock grazing are therefore in the interior parts of southwestern Oregon, high mountain meadows of the Cascade Range, and along valley bottom corridors of coastal streams.

If grazing by livestock on riparian zones and wetlands is heavy and continuous, the vegetation which provides essential habitat for wildlife can be reduced, changed, or eliminated (Kennedy 1977, Platts 1981, Storch 1979, Thomas et al. 1979b, U.S. Environmental Protection Agency 1979). Uncontrolled grazing of palatable plants often prevents reproduction of desired species and can eventually bring about a complete conversion of vegetative type. Existence of older shrubs and trees that provide required habitat structure for many species of wildlife may be eventually precluded by consumption and by trampling of seedlings (Dahlem 1979, Kennedy 1977).

In addition, heavy livestock use in riparian zones and wet meadows can result in undesirable changes in stream channel morphology, lowered water tables and eventual conversion to dry-site plant species and different types of habitat (Bowers et al. 1979, Platts 1981).

Generally, protection of riparian zones and wetlands can be enhanced by recognition of three basic realities:

1. The heavier the grazing use and longer the grazing period, the more severe the impacts will be on these habitats;
2. Physiological needs of shrubs and trees have not been a priority of past

grazing systems which considered primarily the production and maintenance of grasses and forbs to the exclusion of woody vegetation in riparian areas; and

3. Because of habitat requirements for dependent resources, multiple resource considerations, and high values, different grazing strategies should be applied to riparian zones and wetlands than to upland areas.

Because of the high degree of variability within riparian zones and wetlands, managers can make better decisions by using recommendations of an interdisciplinary team which has analyzed site-specific conditions.

To insure that riparian zones and wetlands remain in satisfactory condition for wildlife use, managers responsible for developing livestock grazing programs should take into consideration the following management principles (Bowers et al. 1979, Platts 1981, Storch 1979, Thomas et al. 1979b, U.S. Environmental Protection Agency 1979):

- If significant livestock use is contemplated, present and potential habitat conditions should be key considerations in determining the grazing management prescribed for specific areas. Where habitat is in unsatisfactory condition, grazing practices and systems that will achieve the desired habitat objectives should be implemented:
  - defer grazing in riparian zones until late fall months;
  - fence and apply rest rotation grazing systems;
  - improve off-stream distribution of livestock by providing alternate sources of water to attract animals away from riparian zones and wetlands;
  - provide salting away from riparian zones and wetlands;
  - utilize periodic herding; and
  - improve rangeland condition by revegetation, prescribed burning, etc.

- To obtain management objectives for important riparian zones and wetlands that have been severely impacted from past use, it may be necessary to allow complete rest from livestock grazing for several years by fencing, which appears to be the only present management technique capable of producing the desired results (U.S. Environmental Protection Agency 1979). It may be a permanent requirement to control livestock use in the most important wildlife habitats. However, permanent elimination of livestock grazing in most other areas may be neither feasible nor desirable, but grazing should be closely controlled to improve habitats in poor condition and to maintain healthy riparian habitats in productive conditions.

- To prevent undesirable alterations of the water source and to maintain wildlife habitats, exclude livestock from parts of wet meadows, springs, and seeps by fencing. Necessary water for livestock should then be piped outside the exclosure into a trough(s) (fig. 15).

- Artificial revegetation of riparian zones and wetlands may result in more rapid response than natural recovery, particularly with native shrubs and trees. Plantings must be protected from heavy grazing to achieve desired results.

- In the planning process, part of the vegetation in riparian zones and wetlands should be allocated to wildlife use at the same time forage is allocated for livestock use.

Mining Operations

Mining activities have frequently occurred in riparian and wetland habitats, resulting in substantial surface disturbance. Whenever a valuable mineral deposit is located, mining can preempt any other land use because of the Mining Law of 1872 – unless the land has been specifically withdrawn from mineral development. Because of this, other resource uses can be precluded by mining.

Gravel and sand mining from floodplains and stream channels has been common throughout forest lands of western Oregon and Washington because it is a convenient and relatively inexpensive source of construction material. Riparian zones adjacent to numerous streams have been greatly altered, first by removal of vegetation and then by taking gravel for construction of logging roads. This practice of mining sand and gravel from streambeds and streambanks has been greatly reduced in recent years by laws and regulations to protect water quality and aquatic habitats. Most rock for logging roads is now mined from quarries or open pit mines thus reducing adverse impacts to riparian zones.

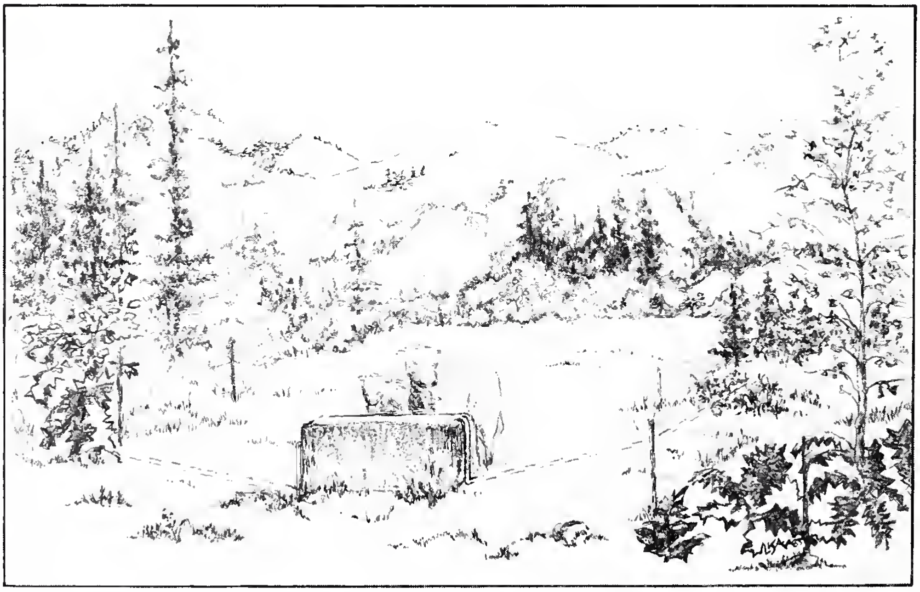


Figure 15.—Important wildlife habitat around springs can be maintained and/or enhanced by fencing small areas to exclude livestock. Water for livestock can be piped outside the exclosure into troughs. Additional wet meadow habitat can be created and maintained by piping overflow water into small fenced areas.

Gold mining by hydraulic (placer) methods has been common in parts of southwestern Oregon. Hydraulic mining for gold in streams and riparian areas can be particularly destructive inasmuch as this activity completely removes vegetation and subsequently creates unstable piles of larger rocks and rubble. Basic productivity of the site for vegetation and habitat quality is drastically reduced.

Protective stipulations and rehabilitation measures should be included in mining plans to minimize impacts on riparian zones and wetlands and to assist in recovery of satisfactory habitat conditions. Access roads should be located outside riparian zones and wetlands. Vegetation removal and surface disturbances should be minimized. Vegetation should be re-established in disturbed areas as soon as mining operations are terminated.

Recreation Management

Construction of recreational facilities in riparian zones increases recreational use which increases the potential for conflicts with wildlife (Thomas et al. 1979a). The impact on wildlife and riparian zones and wetlands depends on the season, type, duration, and magnitude of use. Habitats can be adversely affected by destructive acts, and human disturbance in areas around recreational developments is a major consideration. Campgrounds, picnic tables, and trails should be located outside riparian zones whenever possible.

Recreational facilities should not be located in areas such as heron rookeries, bald eagle nest sites, or important wintering areas for big game. Detailed guidelines for protecting bald eagles are given in chapter 13. Off-road vehicle use in riparian zones and wetlands should be prohibited or closely controlled to prevent undesirable damage to these sensitive habitats.

Energy Development

The construction of dams to generate electricity results in the elimination of existing riparian and wetland habitats located in floodplains inundated by the backwaters of the dam. For many wildlife species, natural migration routes may be disrupted by these backwaters. Vegetation in downstream riparian zones and the natural erosion/deposition process can also be altered if natural stream discharge patterns are changed significantly by the operation of hydroelectric facilities. Some tree species are more tolerant to flooding and saturated soil conditions, while other species are more resistant to drought (Minore and Smith 1971, Walters et al. 1980).

The impact of each dam depends on the amount of habitat lost in relation to the total available local habitat. Compensation by development of like habitat in another location is often not feasible. Other factors being equal, low-head hydrologic projects should be located where they will result in the smallest loss of riparian and wetland vegetation. If more than one such project is located or proposed for an area, the cumulative effects of all the projects should be assessed.

Other large energy developments like geothermal and fossil fuel (coal) plants, or oil and gas production fields have not been major energy producers in past years. Impacts of any such future large-scale, developments on riparian zones and wetlands would have to be analyzed on a site-by-site basis. Impacts and mitigation, however, would be similar to some of the management activities previously discussed in this section.

Wood Fuels

Standing dead trees (snags) and down (windthrown) trees in riparian zones provide important habitats for many wildlife species (see chapters 7 and 8). Large old-growth boles create the habitat diversity characteristics of old-growth forest (Franklin et al. 1981). Optimum wildlife habitat conditions cannot be achieved in riparian zones if many snags and down dead trees are removed for firewood or as marketed forest residue (salvage material) for fuel to produce heat, steam or other products.

Rehabilitation and Enhancement

When riparian zones and wetlands are in satisfactory condition for wildlife, the best management generally is to allow the natural ecosystems to function with minimal disruption. This approach is usually the least costly and most effective way to manage for all native wildlife populations. Simply stated, it means protection from major disturbances caused by man.

Rehabilitation of altered habitats can be hastened by various techniques which promote natural recovery to desired conditions and prevent further deterioration. Some of these methods are listed in habitat improvement handbooks (Nelson et al. 1978, USDA Forest Service 1969). Recommended grasses, shrubs and trees to use for revegetating riparian zones and wetlands in western Oregon are listed in an interagency seeding guide (State of Oregon 1980b).

Enhancement of habitat can often be accomplished by creating more diversity, but a thorough field evaluation should precede any plans to enhance riparian and wetland habitats. Projects should be designed to achieve specific habitat objectives developed for that area. Examples of enhancement projects in riparian zones and wetlands are (1) vegetative plantings of native or preferred wildlife food species, (2) construction of nesting islands or installation of nest boxes, and (3) vegetation manipulation.

Summary

Riparian and wetland habitats are among the most important for wildlife in managed forests, with the riparian zones particularly significant for forest wildlife. Forest managers are only just beginning to recognize the importance of these habitats in providing a variety of wildlife populations for people to enjoy. Riparian zones and wetlands, however, have high potential for resource management conflicts among commodity producers. Managers, with the advice of resource specialists,should seek creative ways to manage these habitats or maintain and improve their productivity. This will be an interesting and important challenge. It is one which will require considerable effort if satisfactory management plans are to be developed and implemented successfully.

References Cited

Bilby, R. E.; Likens, G. E. Importance of organic debris dams in the structure and function of stream ecosystems. Ecology 61(5): 1107-1113; 1980.

Bowers, W. L.; Hosford, W. E.; Oakley, A. L.; Bond, C. E. Native trout. In: Thomas, J. W.; Maser, C.; tech. eds. Wildlife habitats in managed rangelands — the Great Basin of southeastern Oregon. Gen. Tech. Rep. PNW-84. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 16 p.

Brinson, M. M.; Swift, B. L.; Plantico, R. C.; Barclay, J. S. Riparian ecosystems: their ecology and status. FWS/OBS-81/17. Kearneysville, WV: U.S. Department of the Interior, Fish and Wildlife Service, Biological Services Program; 1981. 155 p.

Brown, G. W. Predicting the effect of clearcutting on stream temperature. J. Soil and Water Cons. 25: 11-13; 1970.

Brown, G. W. Forestry and water quality. Corvallis, OR: Oregon State University Book Store, Inc.; 1974. 74 p.

Brown, B.; Henderson, J.; McShane, T.; [and others]. Riparian vegetation/streambank stability inventory. Olympia, WA: U.S. Department of Agriculture, Forest Service, Olympic National Forest, Mimeo. Rep.; 1980. 24 p.

Brown, S.; Brinson, M. M.; Lugo, A. E. Structure and function of riparian wetlands. In: Johnson, R. R.; McCormick, J. F., tech. coord. Strategies for protection and management of floodplain wetlands and other riparian ecosystems. Proceedings of the symposium; 1978 December 11-13; Calloway Gardens, GA. Gen. Tech. Rep. WO-12. Washington, D.C.: U.S. Department of Agriculture, Forest Service; 1979: 17-31.

Bryant, M. D. Evolution of large organic debris after timber harvest: Maybeso Creek, 1949 to 1978. Gen. Tech. Rep. PNW-101, Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 30 p.

Buckman, H. O.; Brady, N. C. The nature and properties of soil. 7th ed. London: Macmillan and Company; 1972. 653 p.

Buol, S. W.; Hole, F. D.; McCracken, R. J. Soil genesis and classification. Ames, IA: Iowa State University Press; 1973. 404 p.

Burwell, D. Prevention of debris accumulation in streams by uphill felling. In: Proceedings of a symposium: Forest land uses and stream environment. 1970 October 19-21; Corvallis, OR: Oregon State University; 1971: 118-120.

Cairns, J., Jr. The recovery process in damaged ecosystems. Ann Arbor, MI: Ann Arbor Science Publishers, Inc.; 1980. 167 p.

Campbell, A. G.; Franklin, J. F. Riparian vegetation in Oregon's western Cascade Mountains: composition, biomass, and autumn phenology, Bull. No. 14, Coniferous Forest Biome, Ecosystem Analysis Studies, Seattle, WA: University of Washington; 1979. 90 p.

Carey, A. B.; Sanderson, H. R. Routing to accelerate tree-cavity formation. Wildl. Soc. Bull. 9(1): 14-21; 1981.

Carothers, S. W. Importance, preservation, and management of riparian habitats; an overview. In: Johnson, R. R.; Jones, D. A.,tech. coord. Importance, preservation and management of riparian habitat: a symposium; 1977 July 9; Tucson, AZ; Gen. Tech. Rep. RM-43. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1977: 2-4.

Collotzi, A. W. A systematic approach to the stratification of the valley bottom and the relationship to land use planning. Ogden, UT: U.S. Department of Agriculture, Forest Service; 1978.

Cowardin, L. M.; Carter, V.; Golet, F. C.; LaRoe, E. T. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. Washington, DC: U.S. Fish and Wildlife Service; 1979. 103 p.

Cummins, K. W. Structure and function of stream ecosystems. Biosci. 24: 631-641; 1974.

Cummins, K. W. The multiple linkages of forests and streams. In: Waring, R. H., ed. Forests: Fresh perspectives from ecosystem analysis. Corvallis, OR: Proc. 40th Annual Biol. Colloq; Oregon State University Press; 1980: 191-198.

Dahlem, E. A. The Mahogony Creek watershed—with and without grazing. In: Cope, O. B., ed. Proceedings of the forum-grazing and riparian stream ecosystems; 1978 November 3-4; Denver, CO: Trout Unlimited: 1979: 31-34.

Dimock, E. J., II. Animal populations and damage. In: Environmental effects of forest residues management in the Pacific Northwest: A state-of-knowledge compendium. Gen. Tech. Rep. PNW-24. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1974: 01-028.

Dyrness, C. T. Soil surface conditions following skyline logging. Res. Note PNW-55. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1967. 8 p.

Erman, D. C; Newbold, J. D.; Roby, K. B. Evaluation of streamside buffer strips for protecting aquatic organisms. Cont. No. 165. Davis, CA: Calif. Water Resour. Center, University of California; 1977. 48 p.

Ewel, K. C. Riparian ecosystems: conservation of their unique characteristics. In: Johnson, R. R.; McCormick, J. F. tech. coord. Strategies for protection and management of floodplain wetlands and other riparian ecosystems. Proceedings of the symposium; 1978 December 11-13; Calloway Gardens, GA. Gen. Tech. Rep. WO-12. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979: 56-61.

Federal Water Pollution Control Administration. Industrial waste guide on logging practices. Portland, OR: U.S. Department of the Interior, Federal Water Pollution Control Administration, Northwest Region; 1970. 50 p.

Franklin, J. F.; Dyrness, C. T. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1973. 417 p.

Franklin, J. F.; Cromack, K. Jr.; Denison, W.; [and others]. Ecological characteristics of old-growth Douglas-fir forests. Gen. Tech. Rep. PNW-118. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Staion; 1981. 48 p.

Froehlich, H. A. Logging debris—managing a problem. In: Proceedings of a symposium: Forest land uses and stream environment. 1970 October 19-21; Corvallis, OR: Oregon State University; 1971: 112-117.

Gard, R. Effects of beaver on trout in Sagehen Creek, California. J. Wildl. Manage. 25(3): 221-241; 1961.

Greene, G. E. Land use and trout streams. J. Soil and Water Cons. 5(3): 125-126; 1950.

Hair, J. D.; Hepp, G. T.; Luckett, L. M.; [and others]. Beaver pond ecosystems and their relationships to multi-use natural resource management. In: Johnson, R. R.; McCormick, J. F., tech. coord. Strategies for protection and management of floodplain wetlands and other riparian ecosystems: Proceedings of the symposium: 1978 December 11-13; Calloway Gardens, GA. Gen. Tech. Rep. WO-12. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979: 80-92.

Harr, R. D. Forest practices and streamflow in western Oregon. Gen. Tech. Rep. PNW-49. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1976. 18 p.

Harr, R. D. Streamflow after patch logging in small drainages within the Bull Run Municipal Watershed, Oregon. Res. Pap. PNW-268. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 16 p.

Harr, R. D.; Krygier, J. T. Clearcut logging and low flows in Oregon coastal watersheds. Res. Note No. 54. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University; 1972. 3 p.

Harr, R. D.; McCorison, F. M. Initial effect of clearcut logging on size and timing of peak flows in a small watershed in western Oregon. Water Resour. Res. 15(1): 90-94; 1979.

Harr, D. R.; Fredriksen, R. L.; Rothacher, J. Changes in streamflow following timber harvest in southwestern Oregon. Res. Paper PNW-249. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 22 p.

Harris, D. D. Hydrologic changes after clearcut logging in a small Oregon coastal watershed. J. Res. U.S. Geol. Surv. 1(4): 487-491; 1973.

Heede, B. H. Influences of a forest on the hydraulic geometry of two mountain streams. Water Resour. Bull. 8(3): 523-530; 1972.

Heller, D. A.; Maxwell, J. M. Development of a riparian area classification and management system on the Siuslaw National Forest, Oregon. Unpublished paper. Corvallis, OR: U.S. Department of Agriculture, Forest Service, Siuslaw National Forest; 1980.

Jackman, S. M. Woodpeckers of the Pacific Northwest: their characteristics and their role in the forests. Corvallis, OR: Oregon State University; 1974. 147 p. Thesis.

Johnson, M. G.; Beschta, R. L. Logging, infiltration capacity, and surface erodibility in western Oregon. J. For. 78(6): 334-337; 1980.

Kelly, W.; Hubbell, R.; Lee, S.; Shikany, L. Management of riparian habitats. Coordination guidelines for wildlife habitats, No. 9; San Francisco, CA: U.S. Department of Agriculture, Forest Service, California Region; 1975.

Kennedy, C. E. Wildlife conflicts in riparian management: water. In: Johnson, R. R.; Jones, D. A.; tech. coord. Importance, preservation and management of riparian habitat; a symposium; 1977 July 9; Tucson, AZ. Gen. Tech. Rep. RM-43. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1977: 52-58.

Ketcheson, G.; Froehlich, H. A. Hydrologic factors and environmental impacts of mass soil movements in the Oregon Coast Range. WRRI 56. Corvallis, OR: Water Resources Research Institute, Oregon State University; 1978. 94 p.

Lantz, R. L. Fish population impacts. In: Proceedings of a symposium: Forest land uses and stream environments. 1970 October 19-21; Corvallis, OR: Oregon State University; 1971a: 246-268.

Lantz, R. L. Guidelines for stream protection in logging operations. Res. Div. Rep.; Portland, OR: Oregon State Game Commission; 1971b. 29 p.

Larse, R. W. Prevention and control of erosion and stream sedimentation from forest roads. In: Proceedings of a symposium: Forest land uses and stream environments. 1970 October 19-21; Corvallis, OR: Oregon State University; 1971: 76-83.

Leopold, L. B.; Wolman, M. G.; Miller, J. P. Fluvial processes in geomorphology. San Francisco, CA: W. H. Freeman and Co; 1964. 522 p.

Lyon, L. J.; Crawford, H. S.; Czuhai, E.; [and others]. Effects of fire on fauna—a state-of-knowledge review. National Fire Effects Workshop; 1978 April 10-14; Denver CO; Gen. Tech. Rep. WO-6. Washington, DC.: U.S. Department of Agriculture, Forest Service; 1978. 22 p.

Maser, C.; Mate, B. R.; Franklin, J. F.; Dyrness, C. T. Natural history of Oregon coast mammals. Gen. Tech. Rep. PNW-133. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 496 p.

Martin, D. J.; Salo, E. O.; White, S. T.; [and others]. The impact of managed streamside timber removal on cutthroat trout and the stream ecosystem. FRI-UW 8107, Final Report; Seattle, WA: University of Washington, College of Fisheries. 1981. 65 p.

Meehan, W. R.; Swanson, F. J.; Sedell, J. R. Influences of riparian vegetation on aquatic ecosystems with particular reference to salmonid fishes and their food supply. In: Johnson, R. R.; Jones, D. A.; tech. coord. Importance, preservation and management of riparian habitat; a symposium; 1977 July 9; Tucson, AZ: Gen. Tech. Rep. RM-43. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1977: 137-148.

Miller, R. E.; Fight, R. D. Fertilizing Douglas-fir forests. Gen.Tech. Rep. PNW-83. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 29 p.

Minore, D.; Smith, C. E. Occurrence and growth of four northwestern tree species over shallow water tables. Res. Note PNW-160, Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station 1971. 9 p.

Moring, J. R. The Alsea watershed study: effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part III—Discussion and recommendations. Fishery Res. Rep. No. 9. Corvallis, OR: Oregon Department of Fish and Wildlife; 1975. 24 p.

Morisawa, M. E. Streams: their dynamics and morphology. New York: McGraw-Hill; 1968. 175 p.

Nelson, R. W.; Horak, G. C.; Olson, E. Western reservoir and stream habitat improvements handbook. FWS/OBS-78/56, Ft. Collins, CO: U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services; 1978.

Odum, E. P. Fundamentals of ecology. 3d ed. W. B. Saunders, Co., Philadelphia, PA; 1971. 574 p.

Odum, E. P. Ecological importance of the riparian zone. In: Johnson, R. R.; McCormick, J. F. Tech. Coord. Strategies for protection and management of floodplain wetlands and other riparian ecosystems. Proceedings of the symposium; 1978 December 11-13; Calloway Gardens, GA. Gen. Tech. Rep. WO-12. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979: 2-4.

Platts, W. S. Effects of livestock grazing. In: Influence of forest and rangeland management on anadromous fish habitat in western North America. Gen. Tech. Rep. PNW-124, Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 25 p.

Proctor, C. M.; Garcia, J. C.; Galvin, D. V.; [and others]. An ecological characterization of the Pacific Northwest coastal region. FWS/OBS-79/11 through 79/15; 5 vols. Portland, OR: U.S. Fish and Wildlife Service, Biological Services Program. 1980.

Rothacher, J. Increases in water yield following clearcut logging in the Pacific Northwest. Water Resour. Res. 6(2): 653-658; 1970.

Rothacher, J. Does harvest in west slope Douglas-fir increase peak flow in small forest streams? Res. Pap. PNW-163. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1973. 13 p.

Ruth, R. H.; Yoder, R. A. Reducing wind damage in the forests of the Oregon Coast Range. Res. Pap. PNW-7. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1953. 29 p.

State of Oregon, Department of Forestry. Oregon forest practice rules. Salem, OR: Oregon Administrative Rules, Chapter 629, Sections 24-101 through 24-648, 7th Revision, effective 1/10/80. Established under ORS 527.610 to 527.730 and subsection (1) of 527.990; 1980a.

State of Oregon. The Oregon interagency guide for conservation and forage plantings—seeding guide. Joint publication of the state of Oregon (Oregon State University and Oregon Department of Fish and Wildlife), Portland, OR: U.S. Department of Agriculture (Forest Service and Soil Conservation Service) and U.S. Department of Interior (Bonneville Power Administration and Bureau of Land Management); 1980b. 84 p.

State of Washington, Forest Practices Board. Washington forest practices: rules and regulations. Adopted pursuant to chapter 76.09 RCW, Olympia, WA; Washington State Forest Practices Board, Department of Natural Resources; 1982. 76 p. & appendices.

Steinblums, J. I. Streamside buffer strips: survival, effectiveness and design. Corvallis, OR: Oregon State University; 1977. 181 p. Thesis.

Stevens, L. E.; Brown, B. T.; Simpson, J. M.; Johnson, R. R. The importance of riparian habitat to migrating birds. In: Johnson, R. R.; Jones, D. A.; tech. coord. Importance, preservation and management of riparian habitat; a symposium; 1977 July 9; Tucson, AZ. Gen. Tech. Rep. RM-43. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Staion; 1977: 156-164.

Storch, R. L. Livestock/streamside management programs in eastern Oregon. In: Cope, O. B., ed. Proceedings of the forum – grazing and riparian/stream ecosystems; 1978 November 3-4; Denver, CO: Trout Unlimited; 1979: 56-59.

Streetby, L. R. Buffer strips— considerations in the decision to leave. In: Proceedings of a symposium: Forest land uses and stream environments. 1970 October 19-21; Corvallis, OR: Oregon State University; 1971: 194-198.

Swanson, F. J. Geomorphology and ecosystems. In: Waring, R. H., ed. Forests: fresh perspectives from ecosystem analysis. Proc. 40th Annu. Biol. Colloq. Corvallis, OR: Oregon State University Press; 1980: 159-170.

Swanson, F. J.; Gregory, S. V.; Sedell, J. R.; Campbell, A. S. Land-water interaction: the riparian zone. In: Edmunds, R. L., ed. The natural behavior and response to stress of western coniferous forests. Stroudsburg, PA: Dowden, Hutchinson and Ross, Inc.; 1981.

Swanson, F. J.; Lienkaemper, G. W. Physical consequences of large organic debris in Pacific Northwest streams. Gen. Tech. Rep. PNW-69. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1978. 12 p.

Swanson, F. J.; Lienkaemper, G. W.; Sedell, J. R. History, physical effects and management implications of large organic debris in western Oregon streams. Gen. Tech. Rep. PNW-56. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1976. 15 p.

Swanston, D. N. Effect of geology on soil mass movement activity in the Pacific Northwest. In: Youngberg, C. T., ed. Forest soils and land use. Ft. Collins, CO: Proc. Fifth North Amer. For. Soils Conf., Colorado State University; 1978: 89-115.

Swanston, D. N. Impact of natural events. In: Meehan, W. R. tech, ed. Influence of forest and rangeland management on anandromous fish habitat in western North America. Gen.Tech. Rep. PNW-104. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 27 p.

Taber, R. D. Seasonal landscape use by elk in the managed forests of the Cedar Creek drainage, western Washington. Final Report to U.S. Department of Agriculture, Forest Service for June 1, 1974-June 30, 1976, FS-PNW-Grant No. 14 Seattle, WA: University of Washington; 1976. 146 p.

Tabor, J. E. Inventory of riparian habitats and associated wildlife along the Columbia River. Vol. IIA: Corvallis, OR: Report to U.S. Department of the Army, Corps of Engineers, North Pacific Division; Oregon Cooperative Wildlife Research Unit; 1976. 861 p.

Thomas, J. W.; Maser, C.; Rodiek, J. E. Riparian zones. In: Thomas, J. W.; tech. ed. Wildlife habitats in managed forests – the Blue Mountains of Oregon and Washington. Agric. Handbook 553. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979a: 40-47.

Thomas, J. W.; Maser, C.; Rodiek, J. E. Riparian zones. In: Thomas, J. W.; Maser, C.; tech. eds. Wildlife habitats in managed rangelands— the Great Basin of southeastern Oregon. Gen. Tech. Rep. PNW-80. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979b. 18 p.

U.S. Department of Agriculture, Forest Service. Wildlife habitat improvement handbook. Forest Service Handbook, FSH2609.11. Washington, DC: U.S. Department of Agriculture, Forest Service; 1969.

U.S. Department of Agriculture, Forest Service. Vegetation management with herbicides, environmental statement—Siskiyou, Siuslaw and Umpqua forests. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1974. 115 p. & appendices.

U.S. Environmental Protection Agency. Processes, procedures, and methods to control pollution resulting from silvicultural activities. EPA 430/9-73-010. Washington, DC: U.S. Environmental Protection Agency, Office of Air and Water Programs; 1973. 91 p.

U.S. Environmental Protection Agency. Logging roads and protection of water quality. EPA 910/9-75-007. Seattle, WA: U.S. Environmental Protection Agency, Region X, Water Division; 1975. 312 p.

U.S. Environmental Protection Agency. Forest harvest, residue treatment, reforestation and protection of water quality. EPA 910/9-76-020. Seattle, WA: U.S. Environmental Protection Agency, Region X, 1976. 271 p.

U.S. Environmental Protection Agency. Silviculture chemicals and protection of water quality. EPA 910/9-77-036. Seattle, WA: U.S. Environmental Protection Agency, Region X; 1977, 224 p.

U.S. Environmental Protection Agency. Livestock grazing management and water quality protection (state-of-the-art reference document). EPA 910/9-79-67. Seattle, WA: U.S. Environmental Protection Agency and USDI Bureau of Land Management; 1979. 147 p.

Walters, H. M.; Teskey, R. D.; Hinckley, T. M. Impact of water level changes on woody riparian and wetland communities. Vol VIII: Pacific Northwest and Rocky Mountain regions. FWS/OBS-78/94; Kearneysville, WV: U.S. Department of the Interior, Fish and Wildlife Service, Biological Services Program, 1980. 47 p.

Yee, C. S.; Roelofs, T. D. Planning forest roads to protect salmonid habitat. In: Meehan, W.R., tech. ed. Influence of forest and rangeland management of anadromous fish habitat in western North America. Gen. Tech. Rep. PNW-109. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 26 p.

5

Estuaries

Thomas F. Gaumer
Scott L. Benson
Larry W. Brewer
Laimons Osis
Delbert G. Skeesick
Richard M. Starr
Jay F. Watson

Table of Contents

Introduction

Estuaries are a vital component of the coastal wildlife habitat in the Pacific Northwest. Although they normally are removed from the actual forest ecosystem, these habitats can be and have been severely impacted by activities related to forest management.

An estuary has been defined by Pritchard (1967) as "a semi-enclosed coastal body of water which has a free connection with the open sea and within which seawater is measurably diluted with freshwater derived from land drainage." The mouths of all rivers that flow into saltwater in western Oregon and Washington are categorized as estuaries. There are 21 major estuaries in Oregon (fig. 1) and 34 in Washington (fig. 2) containing a mixture of salt and freshwater. Many other small streams discharge directly into the ocean or Puget Sound with minor mixing of salt and freshwater in the river mouth.

Pacific Northwest estuaries vary considerably in size, morphology, freshwater influx, salinity, mixing, and sediment composition. A corresponding range in plant and animal species is also evident. The variation in ecological characteristics is caused by differences in estuary origin, latitude, depth, salt and freshwater mixing, circulation, and types of sediment entering the estuary.

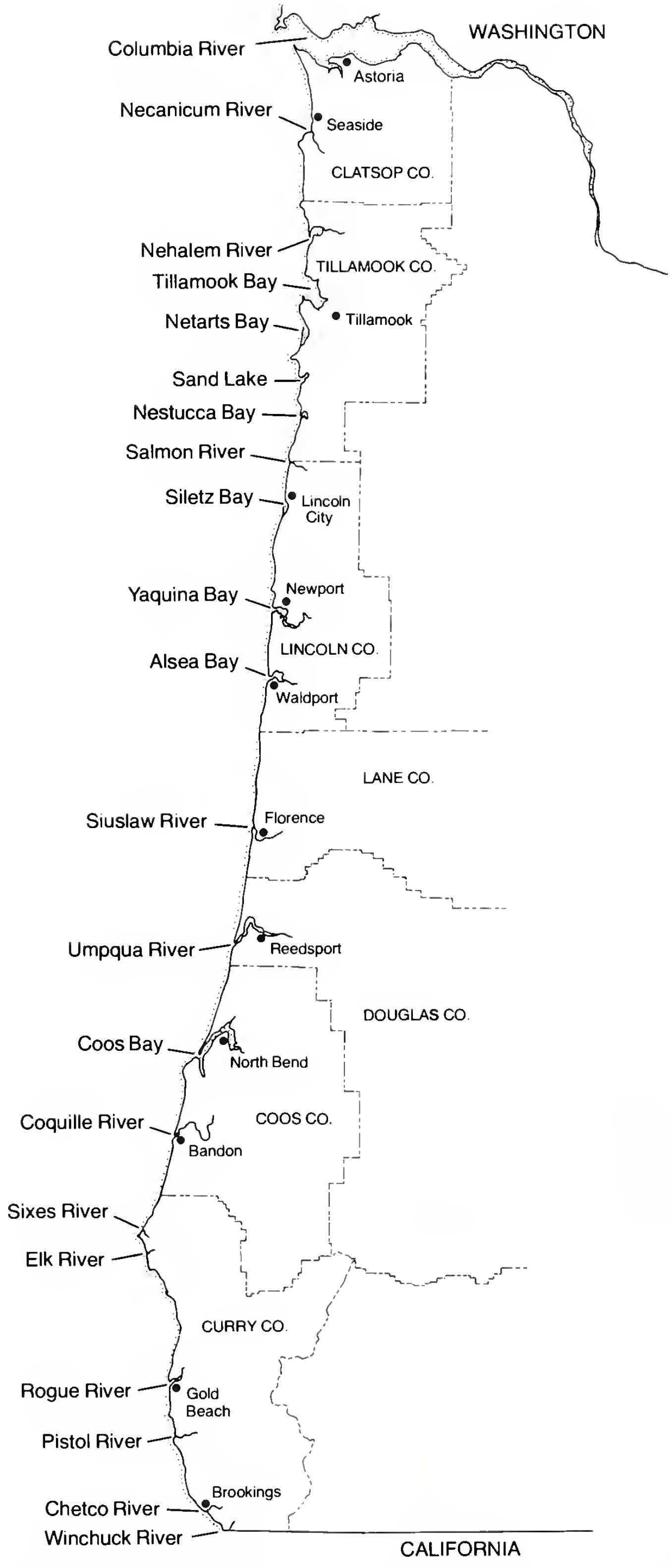


Figure 1.—There are 21 major estuaries along the coast of Oregon. Numerous minor estuaries are not shown.

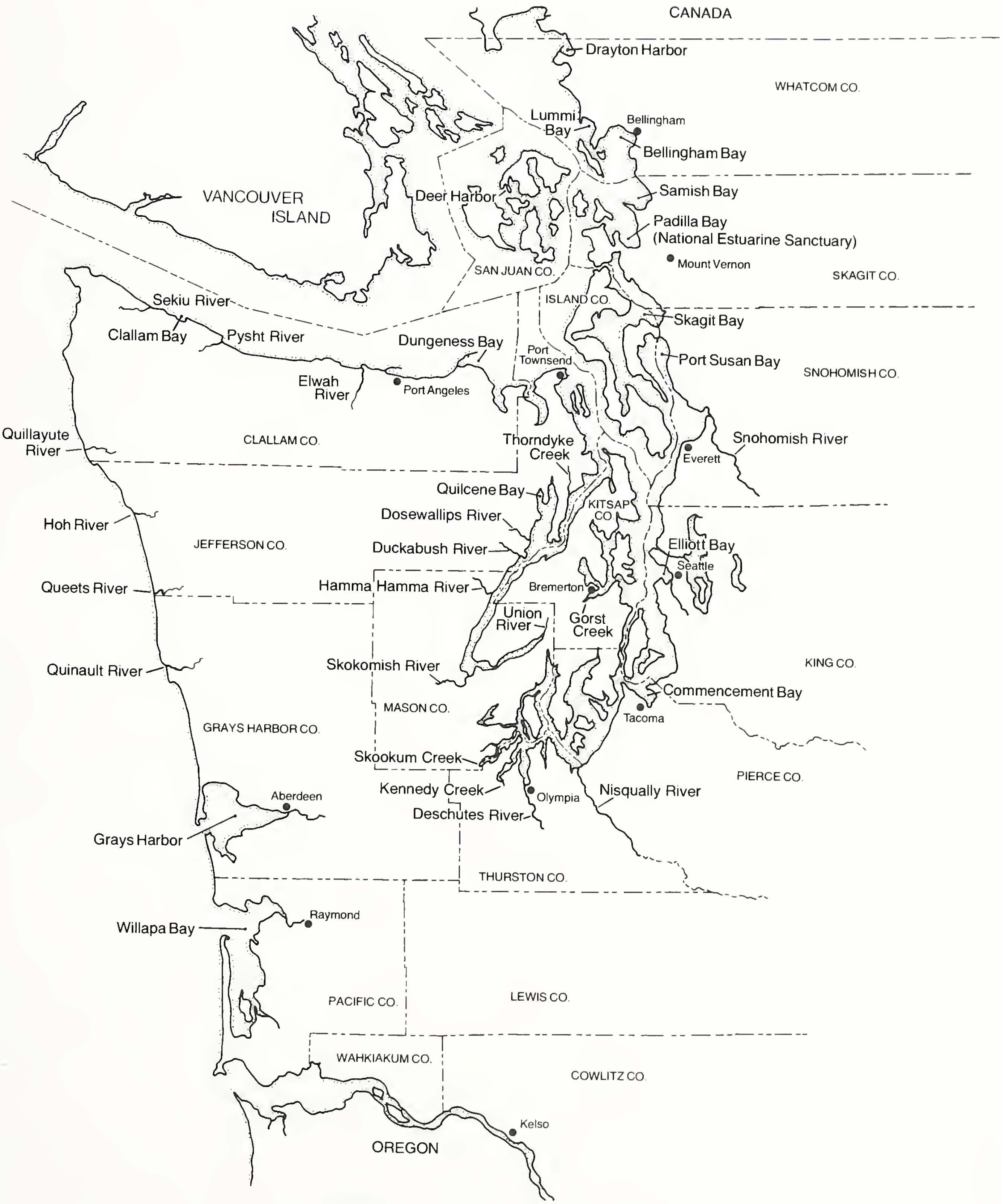


Figure 2.—There are 34 significant estuaries in Washington—6 along the outer coast, 5 along the Strait of Juan de Fuca, and the remainder in Puget Sound.

Although Northwest estuaries vary in size, shape, and biota, the physical and biological processes acting within each estuary are similar. The organisms which inhabit estuaries have evolved special mechanisms to adapt to the stressful conditions caused by daily and seasonal fluctuations in water level, salinity, temperature, and food availability. Many species occupy the wide array of habitats located in each estuary (fig. 3). Species composition in this myriad of habitats varies among estuaries, but comparable niches in each estuary are filled by similar organisms. Therefore, the biological processes of primary production and consumption, and food web relationships are similar for all Pacific Northwest estuaries.

The relationship of estuarine habitats to forest practices is often difficult to evaluate, because in most cases, the estuarine impacts of forest practices are far removed from the actual location of forest alteration. Also, the physical and biological changes that occur in the estuary may not become evident until some time after the forest alteration has taken place. Impacts to the estuary often occur initially as interruptions of lower trophic level food processes, but these ultimately influence higher level organisms. The magnitude of a given change is dependent on the type and amount of material entering the aquatic system, the location where the material is introduced, changes in temperature and light reaching the river and estuary caused by removal of screening vegetation, the circulation characteristics of the estuary, the biota of the estuary, and the time of year.

In some Pacific Northwest estuaries, forest-management activity is the primary source of alteration or degradation of the estuarine environment while in others the picture is further complicated by agriculture, urban and suburban development, or commercial and industrial enterprises. This chapter will limit its discussion to the impacts of forest activities on estuarine habitats and wildlife and provide some management considerations on how the effects of forest practices can be minimized. In order to better understand the importance of estuaries, a brief discussion of estuarine environments and how they function is also included.

Importance of Estuaries

Estuaries are unique systems because they form transitions between terrestrial, freshwater, and marine environments. As transitions between terrestrial and aquatic environments, estuaries contain many edges and ecotones at different scales (see chapter 6 for a discussion of edges). Large scale edges occur at the land-water, water-air, and freshwater-saltwater interfaces. Intermediate scale edges occur at the deepwater-shallowwater and subtidal-intertidal interfaces. Smaller scale edges occur at the boundaries between habitats. The numerous ecotones created by the many edges support a rich and diverse biota.

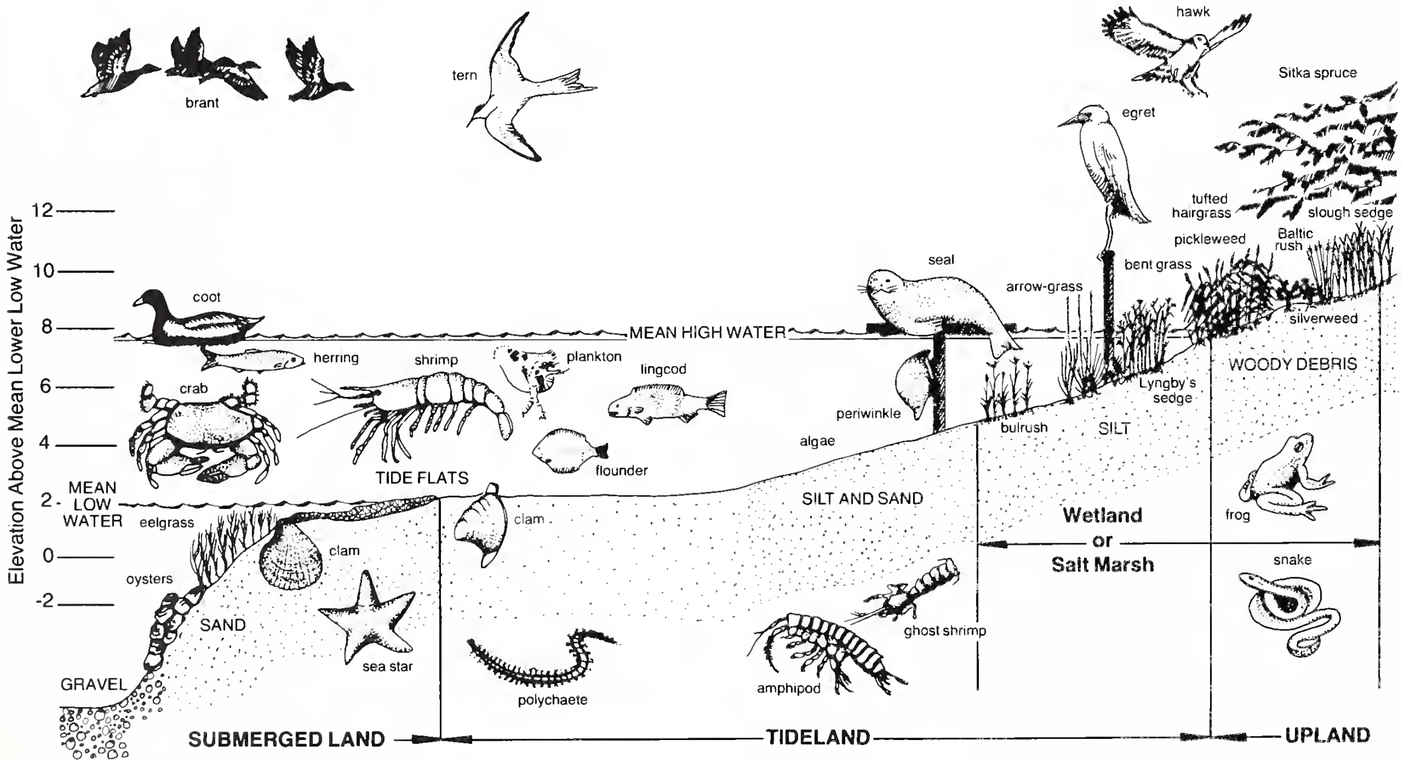


Figure 3.—An estuary is a highly productive ecosystem with a diverse array of wildlife species.

Figure 4.—Virtually all of the black brant in the Pacific Flyway are dependant on northwest estuaries either for wintering or for resting and feeding during migration.

Estuaries harbor many resident species and also provide food, spawning areas, or shelter for numerous other species at critical points in their life cycles (appendices 8, 11, and 12). Some freshwater fish species move downstream into the upper portions of the estuary in the winter to feed and to escape from high velocity floodwaters. Anadromous fish, such as salmon, steelhead, sturgeon, and shad, migrate through the estuary to spawn upstream in freshwater. Juveniles of these species also spend a very critical time rearing in the estuaries prior to emigration to the ocean. With some fall chinook salmon stocks, proper estuarine conditions have been shown to be a prerequisite for survival to adulthood (Reimers 1973). In addition, marine species such as herring, spawn, feed, and rear in extensive areas of estuaries.

Estuaries support large numbers of waterfowl and shorebirds for wintering and during migration (fig. 4) (Herman and Bulger 1981). Results from annual winter inventories compiled by the U.S. Department of the Interior, Fish and Wildlife Service (1979) show that more than 350,000 waterfowl use Washington estuaries and 50,000 use Oregon estuaries during an average winter. Also, a small population of endangered Aleutian Canada geese now winter along the Oregon coast using both major and minor estuaries.

Many of the animal species that inhabit estuaries as juveniles or adults are commercially or recreationally important.

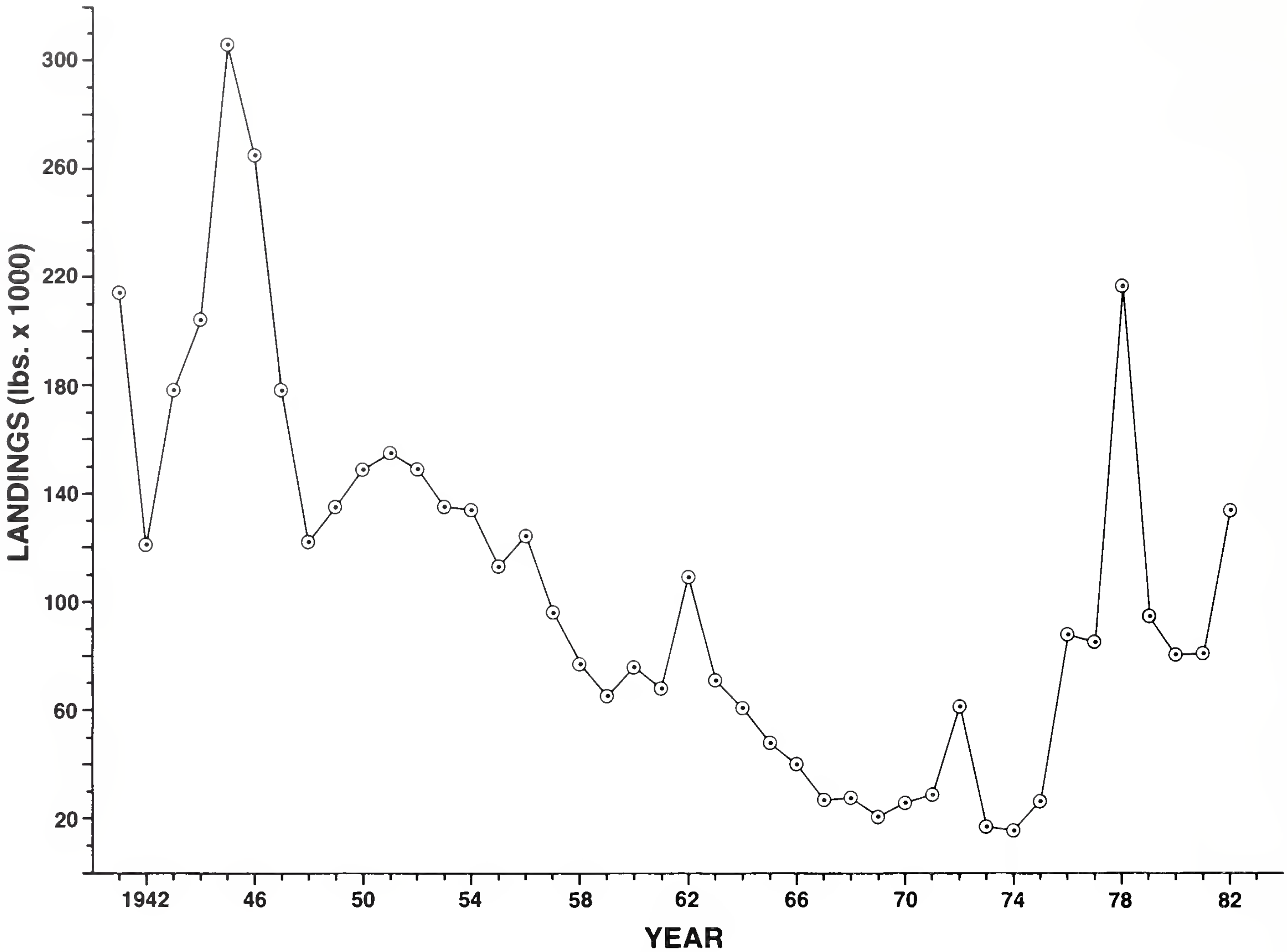


Figure 5.—Commercial bay clam landings in Oregon, 1941-1982 (Oregon Department of Fish and Wildlife, unpublished data).

Estuaries provide spawning and rearing habitat, food, and shelter for species such as salmon, flatfish, and crabs that are generally harvested outside the estuarine ecosystem. Some native wild species such as clams are commercially harvested directly from estuaries (fig. 5), while both native and introduced species of oysters are cultivated for harvest in a number of these productive bays (figs. 6 and 7).

Commercial and recreational fisheries dependent upon estuaries extend economic benefits to supporting industries such as boat repair facilities, fish processing plants, tackle shops, restaurants, motels, etc. Estuarine species also attract bird watchers, botanists, photographers, nature lovers, scuba divers, and other non-consumptive users.

Figure 6.—The production and harvest of oysters has been an important activity in Northwest estuaries since the mid-1800's (Swan 1972).

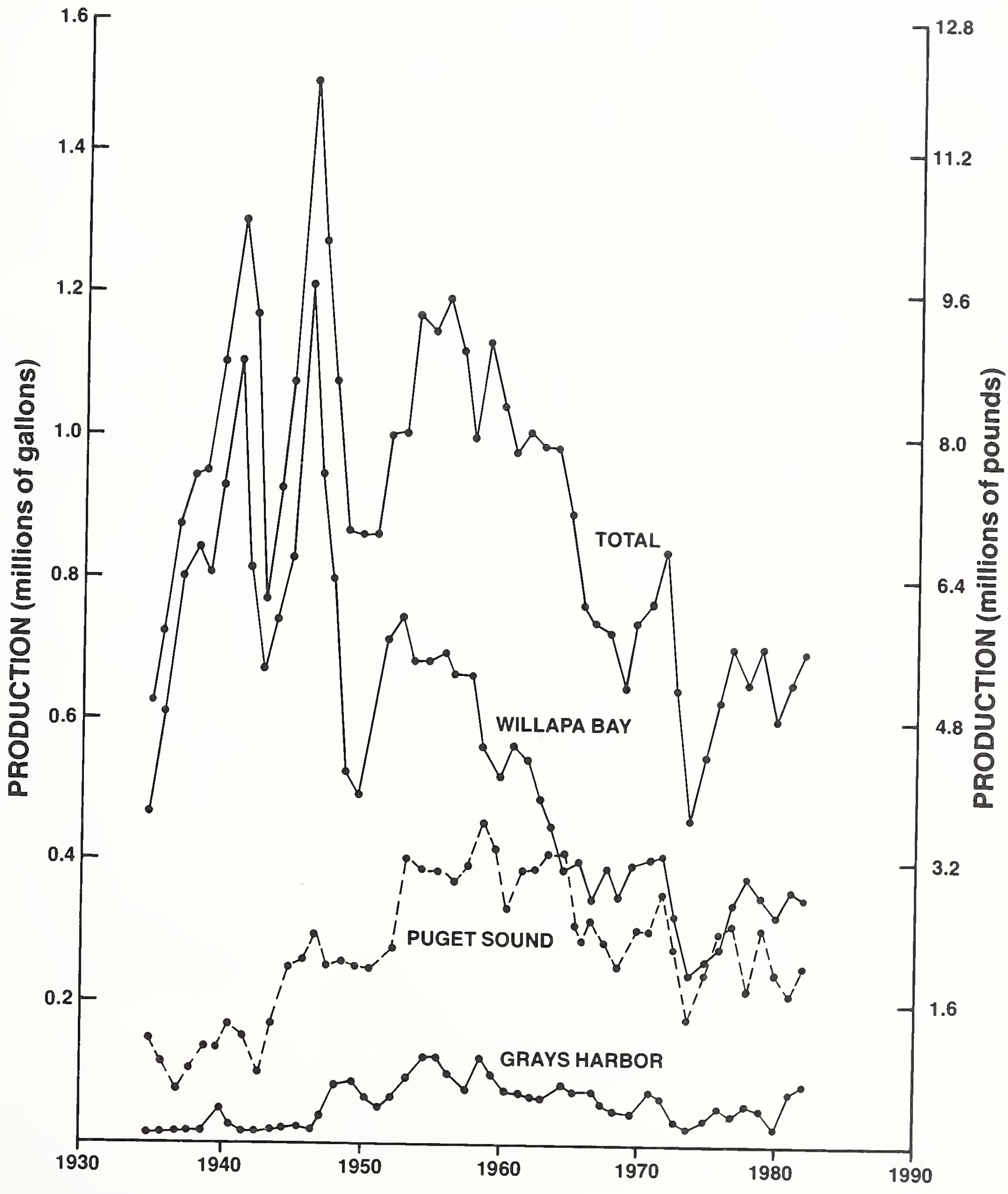


Figure 7.—Washington production of Pacific oysters (*Crassostrea gigas*) 1935 to 1982. (Washington Department of Fisheries data).

Physical Characteristics

Estuaries may be formed by several processes and are morphologically classified into four types: coastal plain estuaries, bar-built estuaries, fjords, and estuaries produced by tectonic processes (Sternberg and Johnson 1978). Three of the four types are found along the Northwest Coast. Coastal plain estuaries are drowned river valleys. The mouth of the Columbia River provides an example of such an estuary. Bar-built estuaries are formed on gently sloping continental shelves by accumulating sand and have extensive tideflat areas. Netarts Bay, Willapa Bay, and Grays Harbor are bar-built estuaries. Puget Sound is an example of a fjord (Rattray, 1967): a steep-walled, deep estuary that was formerly a glaciated valley (Sternberg and Johnson 1978). Estuaries of the fourth type, those produced by tectonic processes such as faulting, folding, or subsidence, are not found in the Pacific Northwest.

Within the estuary, freshwater draining from upland areas meets and mixes with saltwater from the ocean. Salinity can vary from low (freshwater) to high (seawater) within a few miles (sometimes within a few feet), and is the primary physical characteristic determining the distribution of plants and animals in estuaries.

The large volume of freshwater reaching the Pacific Ocean passes through 27 estuaries along the open Oregon and Washington coast and 28 estuaries in Puget Sound and the Strait of Juan de Fuca. These estuaries vary in surface area from less than 1 square mile (Quinault River) to over 146 square miles (Columbia River). The drainage basins which supply the freshwater to these estuaries are also quite variable in size, amount of alteration, and amount of sediment discharge (table 1). Although drainage basin size in Oregon and Washington is variable, basin shapes are similar. Most basins are steep and highly dissected allowing large amounts of water to run off quickly. This causes rapid fluctuations in the salinity of the estuary because of the influx of freshwater after heavy rains.

Table 1—Physical characteristics of major estuaries in Oregon and Washington [1]

Total drainage area (sq mi)	Number of estuaries	Area in forest lands (sq mi)	Annual water discharge (ac/ft)	Annual sediment discharge (tons)
<300	31	6- 233	42,000- 2,050,000	1,387- 100,000
300-1,000	16	289- 870	965,800- 2,989.000	25,000- 1,000,000
>1,000	7	931-3,825	2,400,000-14,280,000	45,600-10,000,000

[1] Pacific Northwest River Basins Commission 1970a, 1970b, 1971; Percy et al. 1974; Proctor et al. 1980; U.S. Geological Survey, 1979; Williams et al. 1975.

The abundant precipitation in western Oregon and Washington produces a seasonally high freshwater runoff to the ocean. Since many coastal watersheds are rather small and low in elevation, peaks of freshwater inflow correspond to winter peaks in rainfall. The Columbia River, with a basin that drains several states, is an exception as its peak runoff corresponds to snow melt in late spring.

The mixing of freshwater with seawater can be classified into three different mixing patterns: stratified, partially mixed, and well mixed (Pritchard 1967). The energy required to mix salt and freshwater is largely supplied by tidal forces. Therefore, a greater tidal range normally means that more mixing occurs. Pacific Northwest estuaries with tidal ranges from 4-10 feet are generally partly or well mixed (Burt and McAlister 1959), with saltwater extending short distances inland.

Currents are important determinants of bottom type, sediment transport, and the distribution of plants and animals in the estuary (Carriker 1967). Current velocities in Pacific Northwest estuaries are usually less than 3 m/h (miles per hour). Velocities of up to 8 m/h, however, have been recorded at the mouth of the Columbia River at peak ebbflow and river discharge (Proctor et al. 1980).

Temperature is also an important factor in the distribution of organisms. In Pacific Northwest estuaries, water temperatures, depending on the season and the size and location of the estuary, have been recorded as high as 83°F in the heat of summer to near freezing during winter cold periods (Lane Council of Governments 1974). The American shad, stocked in the Sacramento and Columbia rivers in 1871 (Welander 1940) and the striped bass introduced to San Francisco Bay in 1879 (Morgan and Gerlach 1950), illustrate the importance of temperature. The American shad is now found along the entire coastline, while viable populations of striped bass, apparently in response to temperature, are found only south of the Columbia River (Hedgpeth and Obrebski 1981).

Estuaries usually possess higher concentrations of nutrients than either ocean surface waters or tributary streams because they receive nutrients from both sources. The combination of these abundant nutrients and strong sunlight make estuaries very suitable for the growth of phytoplankton (microscopic floating plants which convert sunlight via photosynthesis into food). Attached algae and aquatic vascular plants also grow well in this environment.

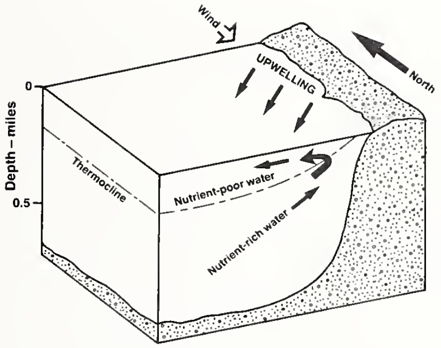


Figure 8.—Waters rich in nutrients are brought to the surface by coastal upwelling and are carried into estuaries by tidal action (from Sumich, James L., BIOLOGY OF MARINE LIFE, 2nd. Ed. fig. 6.15, p. 197. (c) 1976, 1980 Wm. C. Brown Company Publishers, Dubuque, Iowa. Reprinted by special permission).

The Pacific Northwest coastal region, like most westward-facing coastlines in other parts of the world, is an area of intensive upwelling that brings nutrient-rich ocean water to the surface from depths of 300 feet or more (Ricketts and Calvin 1974). Upwelling occurs when winds from the north along the Washington, Oregon, and California coast, in association with the earth's rotational forces, cause surface water to move offshore. Colder, nutrient-rich subsurface water upwells to replace it (fig. 8). Tidal action then carries the nutrient-laden surface water into estuaries, renewing the nutrient content of the estuary.

The other major source of nutrients in Pacific Northwest estuaries is the freshwater inflow of streams entering these estuaries. The largest contributors are the Columbia River and Canada's Frazer River. The nutrient-rich water from these major rivers spreads along the coastline and enters other estuaries through tidal exchange with the nearshore ocean. Local streams, being comparatively small in size, contribute smaller quantities of nutrients, primarily to their own estuaries.

Biological Characteristics

Estuaries vary not only in physical factors such as size, shape, depth and salinity, but in biological characteristics as well. Each estuary has its own assemblages of plants and animals that form unique communities. Each community is formed in response to daily, seasonal, and annual changes in the physical and biological factors that determine individual species distribution. For example, Willapa Bay is a high salinity estuary with extensive eelgrass beds and is the most important oyster production area in the Northwest. The Columbia River estuary, just a few miles to the south of Willapa Bay, has lower salinities, produces no oysters, and supports very limited eelgrass beds.

In order to identify potential forestry related impacts on the estuarine environment, it is necessary to understand some of the characteristics of estuaries and how they function. The following descriptions of the relationships between estuarine plants and the animals that depend upon them are summarized largely from Bahr and Lanier (1981), Hedgpeth and Obrebski (1981), and Peterson and Peterson (1979).

The organisms that inhabit the estuary can be separated into three categories: decomposers, producers, and consumers. The decomposers break down organic material into inorganic nutrients which become available to plant life. The plants are producers of organic material and serve as a forage base for the consumers. The consumers may be either aquatic or terrestrial and either invertebrate or vertebrate. All of these organisms enter into complex food webs or chains where the primary producers are eaten by lower level consumers that in turn are fed upon by higher levels of consumers. Organisms involved may vary from microscopic bacteria and phytoplankton at the lower end to harbor seals and peregrine falcons at the upper end of the food chain. Environmental changes associated with or that result from forest-management operations such as siltation, log storage, dredging, etc., may disrupt the transfer of energy through these food chains causing broad-reaching impacts throughout the estuary.

Decomposers

Most of the organic material that enters Pacific Northwest estuaries comes in either as detritus (small bits and pieces of organic matter) or dissolved organic matter that has leached from living or dead plants (fig. 9). Bacteria and fungi colonize this organic matter and convert it into inorganic nutrients that are necessary for plant production. In this way the bacteria and fungi play an important role in the various geochemical cycles in the estuary (Sverdrup et al. 1942).

Producers

Estuarine plants, the producers, are the basic support for all forms of animal life in the estuary. Nutrient-rich estuarine waters provide for abundant plant growth with high rates of primary production. There are three areas of primary plant production: the salt marsh with rooted aquatic plants, the intertidal area and subtidal flats with algae and eelgrass, and the water column with phytoplankton.

The salt marshes represent transitions between terrestrial and aquatic habitats and provide shelter and food for large numbers of both invertebrate and vertebrate species including fish, amphibians, reptiles, birds, and mammals. Primary production of Pacific Northwest salt

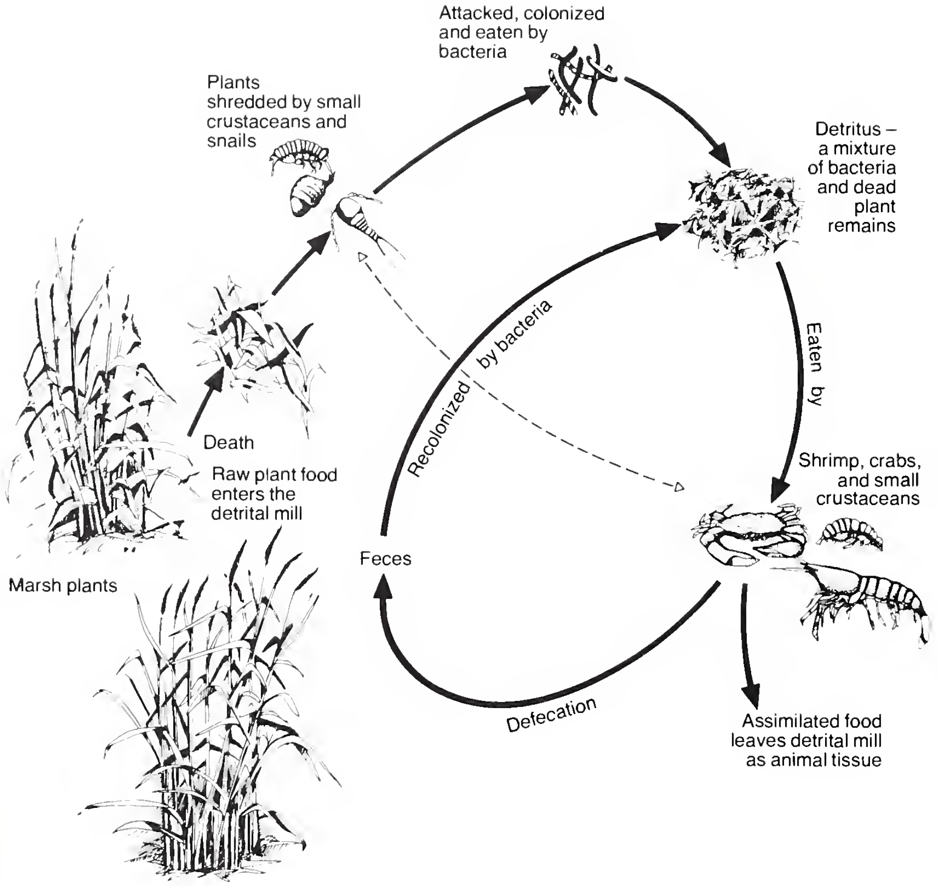


Figure 9.—Marsh grasses feed the detrital mill. Small marsh animals physically shred the dead grass, enabling bacteria to invade it and break it down chemically, so that animals can assimilate it and grow. Their waste products are recolonized by bacteria and the cycle is repeated (adapted from Gosselink 1980).

marshes was found by Eilers (1975) to average 3.3 tons per acre per year as compared to the yield of an average acre of corn of 2.3 tons/acre/year or rice of 2.2 tons/acre/year (Odum 1971).

Although it was long assumed that the salt marsh was the most productive portion of an estuary, recent studies indicate that tideflats and the water column may be even more important components of the primary production. Producers in these areas include eelgrass and tideflat algae which grow in the lower intertidal or subtidal portions of the estuary, and phytoplankton that grows and floats within the water column (Gonor et al. 1979, Thom 1981). In the Nanaimo Estuary in British Columbia, Canada, Naiman and Sibert (1979) found these sources were producing 9.1 tons/acre/year, while Davis and McIntire (1981) reported production of 11.9 tons/acre/year, primarily of tideflat algae, from Netarts Bay in Oregon.

Not only do plants serve as the cornerstone of the grazing food chain in the estuary, they also provide shelter for both invertebrate and vertebrate animal species (Bottom and Forsberg 1978, Markham 1967, Martin et al. 1951, Thayer and Phillips 1977).

Consumers

There are numerous ways in which the animals that form the consumer group feed, capture prey, and reproduce. These adaptations have evolved over time and allow estuarine animals to take advantage of the various habitats found within Pacific Northwest estuaries. Each group of organisms, however, depends on specific habitat requirements for survival. Any change in the chemical or physical characteristics of an estuary may change these habitats in such a way that estuarine organisms no longer have the capability to reproduce or even survive. Consumers using estuaries can be divided into two major groups: aquatic and terrestrial.

Aquatic Consumers

The aquatic consumers consist of both invertebrate and vertebrate species (fig. 10). Invertebrate consumers include the zooplankton which are at the lowest level on the consumer food chain and are free swimming in the water column. Other invertebrates include species such as the clams and worms found in the estuary substrate; mussels, barnacles and oysters attached to the bottom; and crabs or snails that move around on the bottom. Aquatic vertebrate consumers include all species of fish found in the estuary, some bird species, and marine mammals (Peterson and Peterson 1979, Simenstad et al. 1979, U.S. Army Corps of Engineers 1976).

The aquatic consumers are divided into three groups according to their basic habitat requirements. "Zooplankton" are found in the water column. Because they are small microscopic animals occurring in exceedingly large numbers, they process large amounts of organic material. They also are a vital food source for higher trophic level organisms (larger consumers) within the estuary (Hedgpeth 1966).

The second group is called "benthos" and includes those animals that live in close association with the bottom either in the substrate (clams and worms), attached to the bottom (oysters and mussels), or that move along the bottom (snails, crabs, and sea stars). The larval stages of many species of these animals are free swimming in the water column. When they are in the water column, they are classified as zooplankton and constitute an important food source for many of the secondary consumers. The bottom dwelling adult stages, although much larger, are still very numerous in most estuarine areas and have the capability of cycling or turning over organic sediments at a high rate. In addition, the tubes and burrows of many benthic organisms living in the substrate allow oxygen to penetrate to depths otherwise not possible which leads to a greater abundance of animals in the sediments (MacGinitie 1934).

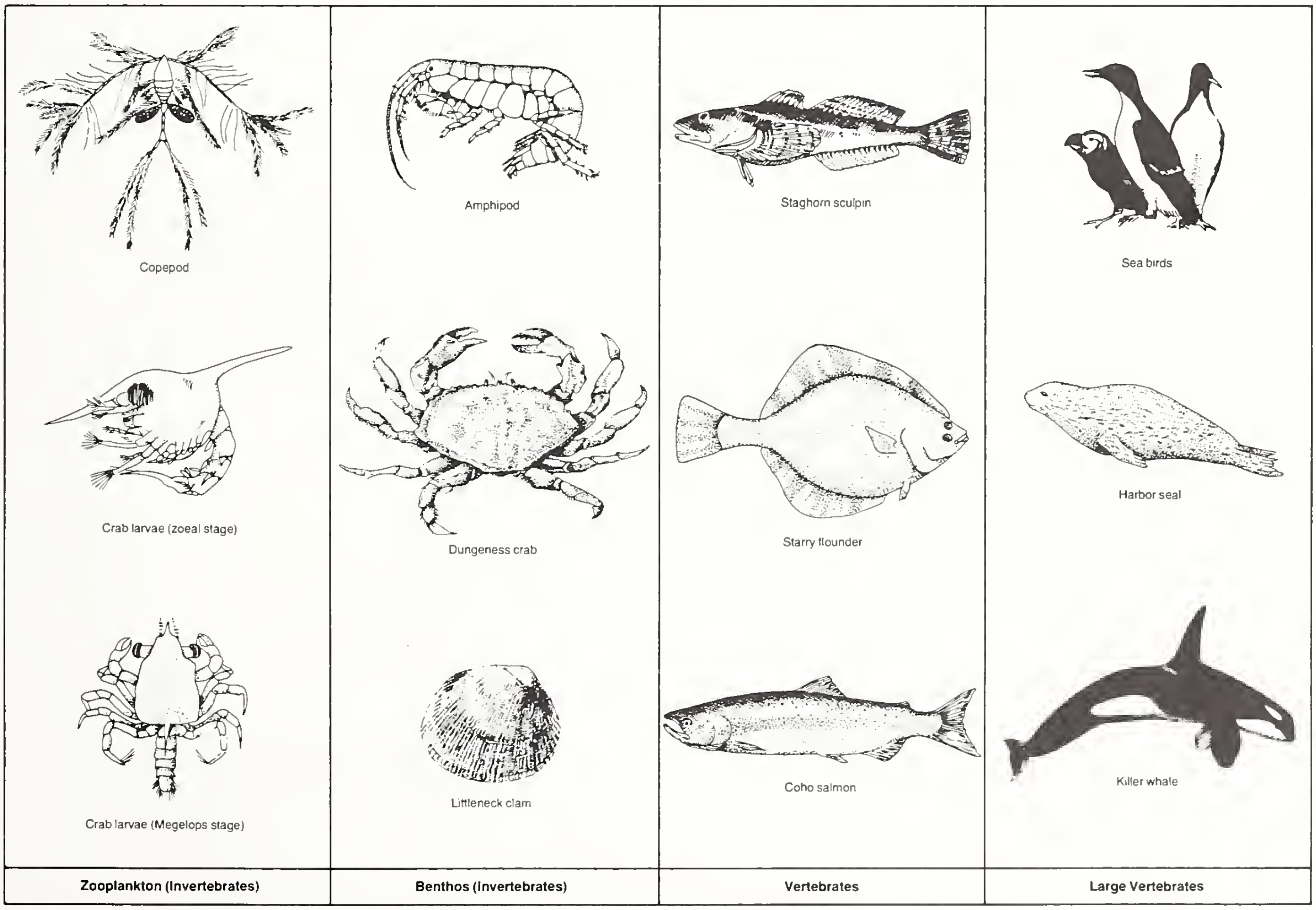
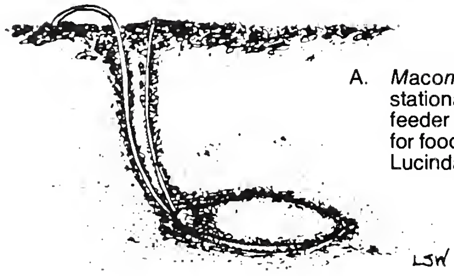


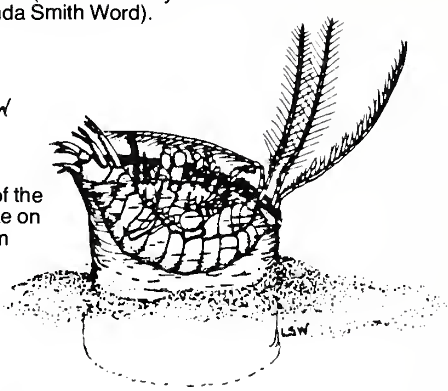
Figure 10.—Some representative examples of the three aquatic consumer groups. Each group and each species within a group occupies a specific habitat niche within the estuary.

Many of the species in the "benthos" group are relatively immobile and employ a wide variety of feeding mechanisms to obtain food from the organic debris found on the estuary floor or suspended in the water column (fig. 11). Because of their sedentary nature and specialized feeding adaptations, this group is highly vulnerable to increased sediment deposition.

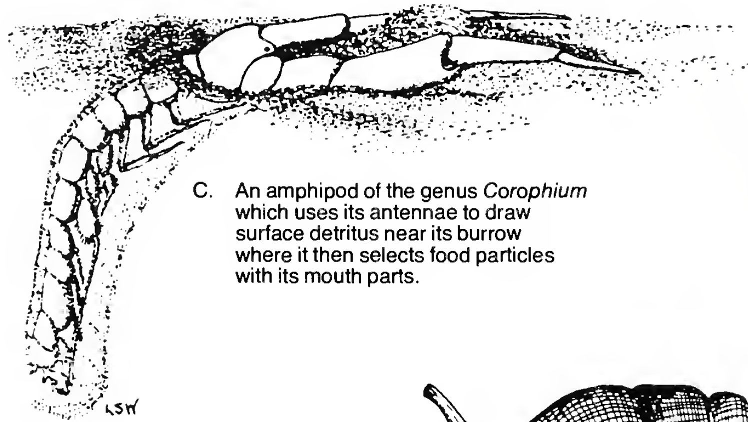
The third aquatic consumer group consists primarily of vertebrate fish species. Most species in this group are free swimming and live in the water column (nekton), but some sea birds are also included in this group. Aquatic vertebrates feed either on organisms in the water column itself or on organisms living on the bottom. The various salmon species, when feeding in estuaries, are included in this group.



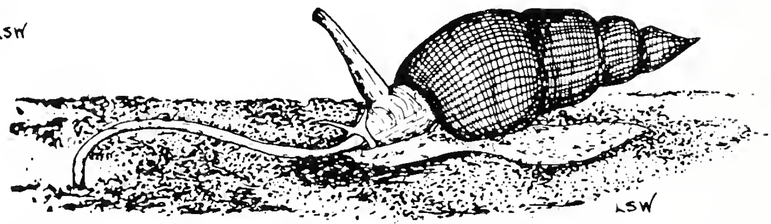
A. *Macoma nasuta* is a relatively stationary surface deposit feeder that actively searches for food (Illustrations by Lucinda Smith Word).



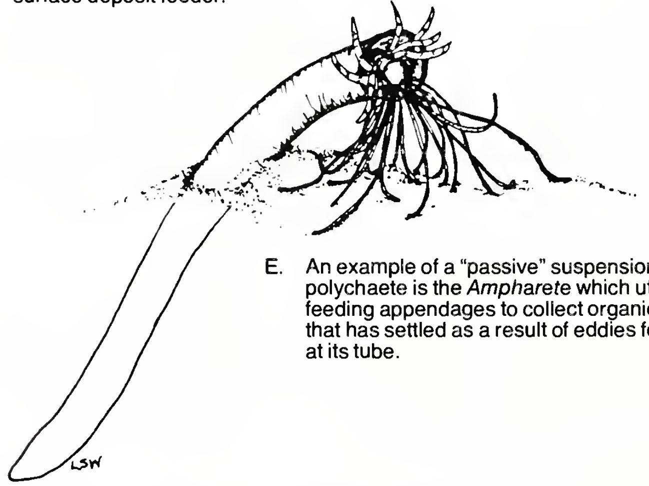
B. A "normal" suspension feeding amphipod of the genus *Ampelisca*. Note the numerous setae on the antennae which are held into the bottom water currents. These setae act as a sieve to collect suspended detritus.



C. An amphipod of the genus *Corophium* which uses its antennae to draw surface detritus near its burrow where it then selects food particles with its mouth parts.



D. The gastropod genus *Nassarius* uses its proboscis to select particles while moving over the surface of the sediment. It is a mobile surface deposit feeder.



E. An example of a "passive" suspension feeding polychaete is the *Ampharete* which utilizes its feeding appendages to collect organic detritus that has settled as a result of eddies formed at its tube.

Figure 11.—Species in the 'benthos' group utilize a variety of feeding adaptations in order to obtain food from the organic debris found either on the floor of the estuary or suspended in the water column (adapted from Bascom 1980).

Terrestrial Consumers

Terrestrial consumers found within or around Pacific Northwest estuaries also include both invertebrates and vertebrates. If the estuary does not provide for all of their needs, it does provide valuable habitat for feeding, resting, and cover.

Terrestrial invertebrate consumers are those species that cannot survive prolonged submersion and move into the intertidal areas only during tidal changes. These species include flies, leaf-hoppers, bees, wasps, ants, and spiders. The spiders are important predators in the intertidal salt marsh system (Schrag 1976). All insects are an important food source for species such as chinook salmon that use the estuarine channels for rearing and migration (Forsberg et al. 1977).

Terrestrial vertebrate consumers include amphibians, reptiles, birds, and mammals. Thirty seven species of mammals are known to use Pacific Northwest estuaries. Shrews, voles, and mice are common inhabitants of the salt marshes. Larger mammals such as the red fox and coyote enter the marshes to prey on the small mammals. Deer and elk rest and forage in these same areas. Raccoons and skunks leave the protection of upland areas to enter marshes and tideflats to feed on invertebrates.

One of the most prominent features of Northwest estuaries is the large number of bird species that use these habitats for feeding, loafing, and nesting. Thousands of migratory birds use the esturaries for feeding and resting during their migration to and from their nesting grounds in the arctic (Herman and Bulger 1981).

Some species of shorebirds probe the tideflats (fig. 12) for the abundant small invertebrates that live in the substrate while others feed on insects in the upper tideflats (Page 1978). Fish-eating birds such as mergansers generally use the deep-water portions of estuaries while waterfowl and shorebirds use the intertidal and shallow subtidal areas more frequently. Birds of prey use the fish, small mammals, and bird species found in estuarine habitats as their forage base.

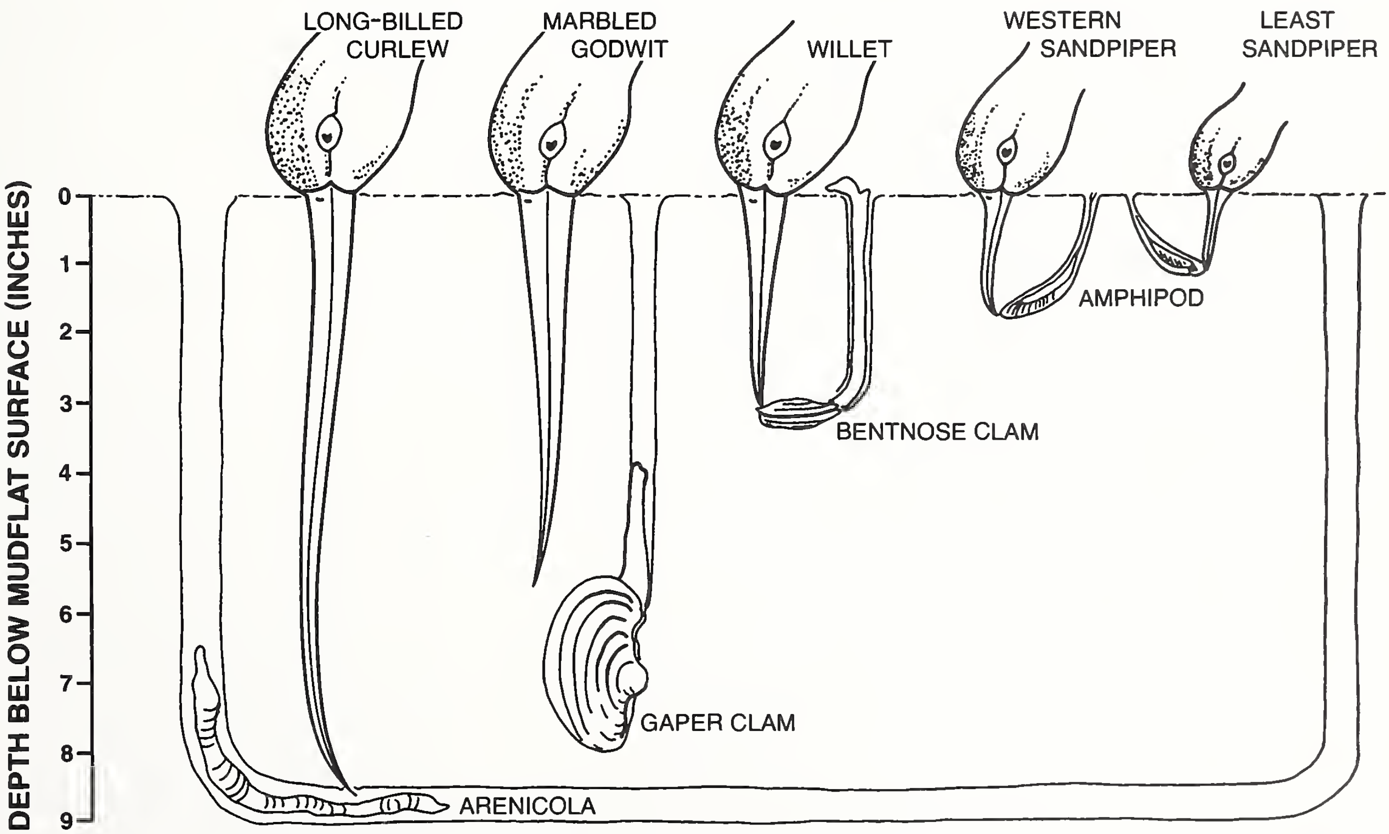


Figure 12.—Feeding adaptations of Pacific Northwest shorebirds (adapted from Green 1975—used with permission).

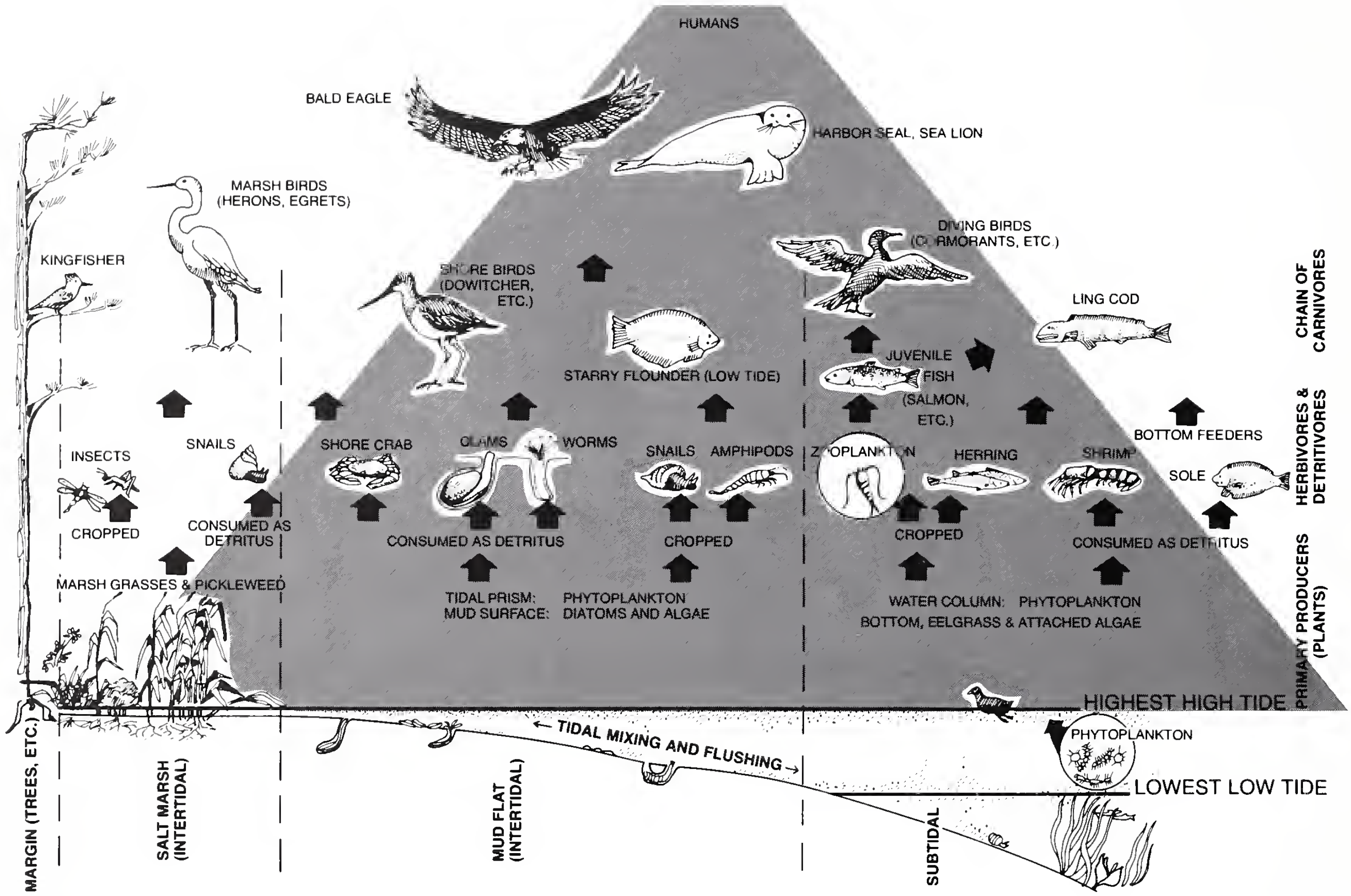


Figure 13.—Simplified food pyramid for a Pacific Northwest estuary (illustration by Taffy Stewart 1982).

Food Webs

Each group of consumers is dependent on one or more primary producers within the estuary. Food webs can be used to illustrate the nutritional interrelationships between estuarine plants and animals. Food webs are a conceptual or graphic way of presenting the flow of energy through an ecosystem, or "who is eating whom" (fig. 13). Numerous food webs have been described for Pacific Northwest estuaries (Proctor et al. 1980, Simenstad et al. 1979). Each food web, although appearing static, changes with season, tide, time of day, and numerous other factors. The primary value of using food webs, however, is in illustrating the transfer of energy between various trophic levels and in predicting possible changes that might influence the transfer of energy.

Estuarine ecosystem food webs are detritus-based, grazer-based, or a combination of the two, depending upon the sources of energy. Detritus or dead organic material is a major source of food for invertebrates, which are in turn eaten by fish, shorebirds, and seabirds. Conversely, water column food webs are based on phytoplankton which are consumed by zooplankton and planktivorous fish. The zooplankton are in turn eaten by fish and the fish are eaten by birds and mammals.

A detritus-based food web might be characterized by dead organic material consumed by an amphipod, that falls prey to a juvenile chinook salmon, which eventually is caught in a commercial troll fishery. A grazer-based food web might begin with floating algae that is grazed on by a copepod, that falls prey to a smelt, then is eaten by a lingcod, and last is caught in a commercial or sports fishery. The relationship between producers and consumers is not static, however, and changes with the various life stages of organisms, availability of prey, and even the time of day or the level of tide.

At the top of the food webs are the major carnivores or predators such as man, marine mammals, and predatory birds. Each of these is dependent on a lower level in the food web for forage, ultimately reaching down to the base of the pyramid which is made up of the primary producers in the estuary. A break in one of the food chains at any level, but particularly at the lower levels, can have a major impact on estuarine-dependent species (Peterson and Peterson 1979). Several forest-related activities, such as sedimentation resulting from road construction or timber harvest, chemical applications in the watershed, or log storage in the esturary, have the potential of breaking or altering food chains.

Effects of Forest Practices on Estuarine Habitats and Wildlife

Forestry activities that influence estuaries may occur either in the watershed at some distance from the estuary, within the estuary itself, or along its adjacent shoreline. Forest activities that occur in the watershed may alter the physical and chemical characteristics of river water flowing into the estuary (fig. 14) and thus indirectly influence estuarine habitats (fig. 15). Forest activities occurring in the estuary or along the adjacent shoreline may directly alter habitats. These practices can also impact wildlife species outside the estuary that depend on the estuary for their livelihood (e.g. blue herons).

Forest Activities (1-Primary cause, 2-Secondary cause)	Increases suspended solids	Reduces light penetration	Increases sediment deposition	Reduces tidal prism	Changes current pattern	Changes river discharge	Changes oxygen concentration	Changes salinity	Changes water temperature	Changes pH	Introduces toxic materials	Physically covers substrate	Changes nutrient cycles
Activities in watershed													
Road building	1	1	1	2	2			2			2		1
Logging	1	1	1	2	2	1	2	2	2	2	2		1
Use of chemicals											1		1
Activities in estuaries													
Landfill	2	2	1	1	1			2		2	2	1	2
Log storage	2	1	2		2		1	2	2	1	1	1	2
Shoreline tree removal	2		2						2	2			

Physical changes caused by forest activities

Figure 14.—Physical changes in estuaries that may result from forest management activities.

Estuarine habitats (1-Severe impact, 2-Secondary impact)	Increased suspended solids	Reduced light penetration	Increased sediment deposition	Reduced tidal prism	Changed current patterns	Changed river discharge	Changed oxygen concentration	Changed salinity	Changed water temperature	Changed pH	Introduced toxic materials	Physically covered substrate	Changed nutrient cycles
Water column	1	1		1		2	2	2	2	2	1		2
Subtidal													
mud	2				2	2	2	2	2	2		1	
mud/sand	2		2		2	2	2	2	2			1	
sand	2		1		2	2	2	2	2			1	
cobble	2		1					2	2			1	
boulder	2		2					2	2			1	
bedrock	2		1					2	2			1	
vegetation	2	1	2	2	2	2	1	2	2	2	2	1	1
Intertidal													
mud	2	2			2	2	2	2	2	2		1	2
mud/sand	2	2	2		2	2	2	2	2			1	2
sand	2	2	1		2	2	2	2	2			1	2
cobble	2	2	1					2	2			1	2
boulder	2	2	2					2	2			1	2
bedrock	2	2	1					2	2			1	2
vegetation	2	2	2	2	2	2	1	2	2	2	2	1	1

Physical changes caused by forest activities

Figure 15.—Impacts that physical changes may have on estuarine habitats.

Physical changes in the estuarine environment, directly or indirectly caused by forest activities, impact numerous estuarine organisms (fig. 16). Selected examples and discussion are presented to demonstrate how environmental changes can impact estuarine species.

Effects of Watershed Activities

Road construction and timber harvesting are the major forestry-related activities occurring in the watershed that influence estuarine habitats. Both activities introduce material into the rivers that flow into estuaries and thus affect estuarine habitats and the wildlife species that use these habitats.

Road construction is typically one of the first preparations for logging (fig. 17). It is also a major source of drainage system sedimentation (U.S. Environmental Protection Agency 1975). The contribution of sediments from logging road systems is often persistent over the long term because, once constructed, some of these roads are maintained and often remain open to public use. Cederholm et al. (1981) found that the presence of 4 miles of gravel-surfaced logging roads in each square mile of the Clearwater River watershed, Jefferson County, Washington, produced sediment at a rate of 2.6 to 4.3 times the natural rate in the drainage basin. They determined that 60 percent of road-related sediment introduced to streams came from landslides along roadways, and 18 to 26

Example	Life form	Reproduces	Feeds	Mobility	Increased suspended solids	Reduced light penetration	Increased sediment deposition	Reduced tidal prism	Changed current patterns	Changed river discharge	Changed oxygen concentration	Changed salinity	Changed water temperature	Changed pH	Introduced toxic materials	Physically covered substrate	Changed nutrient cycles
rockfish	1-A	W	W	M	2	2		2		2		2	2		2		2
cockle clam	1-B	W	W	S	1	2	2	2	2	2	2	1	2	2	2	1	2
crab	1-C	W	B	M			2	2		2		2			2	2	
bentnose clam	1-D	W	B	S			2	1	2	2	2	1	2	2	2	1	
coho salmon	1-E	B	W	M		2	2	2		2		2	1		2	2	2
sea anemone	1-F	B	W	S	2	2	2	2	2	2	2	1	2	2	2	1	
octopus	1-G	B	B	M			2	2		2		2			2	2	
segmented worm	1-H	B	B	S			1	1	2	2	2	1	2	2	2	1	

1-Severe impact 2-Secondary impact

Physical changes caused by forest activities

W – Water column
B – Bottom
M – Mobile
S – Sedentary

Figure 16.—Impacts that physical changes may have on species within the eight estuarine life forms.

Figure 17.—Roads, during the construction phase, and if left unsurfaced after construction, are a major source of drainage system sedimentation.

percent resulted from road surface erosion (fig. 18). This information was substantiated by Gresswell et al. (1979) who reported that road building was a primary cause of mass soil movements in Oregon mountains and that clearcutting was a secondary cause. Reid (1981) reported that roads used by more than 16 trucks per day contributed 1,000 times as much sediment as roads which had been abandoned.

The commercial removal of trees and the associated disturbance of other vegetation and the substrate also adds sediments to streams and rivers in watersheds. Johnson and Beschta (1980) reported that logging increases sediment transport to rivers by increasing surface erodibility and decreasing infiltration capacity.

Soil erosion in a watershed caused by road building and logging increases riverine suspended solids and bedload. Increased sedimentation in the drainage waterways increases sediment deposition rates in the estuary, as rivers are the primary source of sediment to most estuaries (Schubel et al. 1978). River-borne sediments introduced into the estuary increase suspended solids, reduce light penetration, increase sediment deposition, reduce the tidal prism, induce changes in water temperatures, and, depending on organic content of the sediment material, may affect hydrogen ion concentration (pH) and dissolved oxygen. These conditions directly affect reproduction and growth of plants and animals that are at the bottom of the food chain in the estuary. A more detailed discussion of these impacts is included in the following sections.

Suspended Solids

Particles suspended in the water column decrease the transparency of the water and thus the depth light can penetrate. Reduced light impacts plant productivity (fig. 19). Also, reduced light limits the distribution and abundance of the primary producers: phytoplankton, benthic algae, and rooted plants (Pomeroy and Stockner 1976). A decrease in productivity of the primary producers reduces the amount of plant material available as food for primary consumers, which can seriously weaken the base of the food pyramid.

Figure 18.—Roadside vegetation, both adjacent to an estuary and in the watershed above the estuary, should be kept healthy to minimize sediment transport.

Secondary consumers, those higher on the food chain, are also impacted if their primary food source is reduced by suspended solids in the water. Commercially important salmonids and bottom fish feed on estuarine invertebrates during all or part of their life cycles (Gerke and Kaczynski 1972, Levings 1980). When suspended and dissolved solids reduce invertebrate populations, the fish-carrying capacity of the estuary may be diminished (Sigler and Bjornn 1979). A disrupted estuarine food web will impact anadromous fish runs, or the production of bottom fish in the salt water environment.

Even when invertebrate densities are not reduced, those groups of animals which rely on sight to identify their prey have difficulty feeding in murky waters (Sigler and Bjornn 1979). Fish are cold-blooded and reasonably capable of withstanding short periods with no food. Birds and mammals such as diving ducks or harbor seals, with higher metabolism, are more sensitive to food shortages and would be stressed more during periods when high turbidity interrupts feeding (Ohlendorf et al. 1974).

Turbidity also has a direct physical effect on estuarine animals. Loosanoff (1961) observed that in the American oyster, a silt concentration of 0.1 ppm, caused a 57 percent decrease in pumping rates accompanied by abnormal shell movements. The silt interfered with respiration and feeding. At concentrations of 4 to 5 ppm, pumping activity was reduced 90 percent. Prolonged exposure to high silt concentrations resulted in death of the test oysters. Loosanoff's study also revealed that embryonic development and survival of oyster eggs varies with silt concentrations. Concentrations of 0.25 ppm resulted in 27 percent mortality of test oyster eggs, 0.5 ppm yielded 70 percent mortality, and 1 to 2 ppm caused 100 percent mortality in the test eggs. Similar findings were reported by Davis and Hidu (1969).

O'Connor et al. (1976) and Rogers (1969) demonstrated that high concentrations of suspended solids could prove lethal to several estuarine fish species. Several other researchers including Herbert et al. (1961), Herbert and Merkens (1961), Ritchie (1970), and Southgate (1960) found that sublethal concentrations of suspended solids still cause substantial damage to fish, primarily to gill tissue.

O'Connor et al. (1977) also studied the effects of suspended sediments on hematology, gill tissue, carbohydrate metabolism and oxygen consumption in estuarine fish. Their studies showed that most fish were adversely affected when exposed to suspended sediments, i.e. hemoglobin concentration and red blood cell counts increased with exposure to sublethal suspended solids. Gill tissue disruption and intensified mucus production also occurred with exposure. The severity of the effects varied between species, and was dependent on the type of material in suspension and duration of exposure.

Sediment Deposition

Where incoming suspended solid concentrations are moderate to low, estuarine currents carry much of the suspended material out of the estuary, and net sediment deposition is minor. Conversely, in watersheds where forest-management activities elevate suspended solid concentrations, high sediment deposition rates occur in the estuaries, and many substrates are buried (fig. 20). Substrates most affected are those used by plants and animals for attachment, spawning, feeding, and shelter. For example, macroscopic algae attach to large rocks, herring and lingcod spawn on rocks or other rough materials where their eggs can adhere until hatched, and sea stars feed on mussels that are attached to solid items. In addition small crabs use the spaces between rocks and shells as hiding cover. When substrate burial occurs, those animals that are attached to the substrate and cannot move, and those whose life stages require hard surfaces, are killed.

Particles suspended in the water column and deposited on the substrate also carry adsorbed pollutants, such as halogenated hydrocarbons, pesticides, metals, and oils (Schubel et al. 1978). Filter-feeding and deposit-feeding organisms ingest the particles carrying adsorbed pollutants. This provides a concentration of contaminants in the food chain and begins the process of biomagnification, in which toxic materials are transferred to and concentrated in animals in higher trophic levels (Schubel et al. 1978).

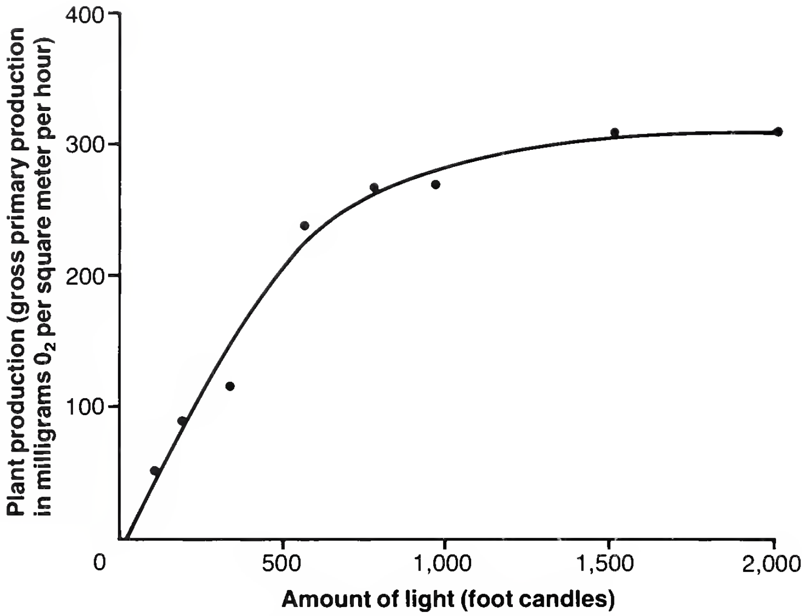


Figure 19—Relationships between plant production and light intensity (Warren and Doudoroff 1971).

Figure 20—River currents slow as they enter the estuary and suspended solids settle. The resulting sediment buildup changes species composition in the estuary.

A less obvious, but more insidious effect of increased sedimentation is the reduction of the overall tidal prism or size of the estuary that occurs when bedload and suspended sediments are deposited in the estuary. The gradual deposition of fine particles in the slower moving portions of estuaries eventually reduces water depth causing greater portions of the estuary to be exposed for longer periods during low tide (fig. 21). Ultimately, those species less able to withstand long periods of exposure to the sun and the drying effect of the wind, are replaced by those that have adapted to an existence in the higher intertidal area (Smith 1977). A reduction in the tidal prism also causes a larger part of the estuary to be under the influence of freshwater for longer periods of time. Biota unable to adjust to a less saline habitat are again replaced by species more tolerant of freshwater. The ultimate result is the filling in of the estuary and the replacement of highly productive estuarine habitat valuable to many species of wildlife, with less productive upland habitat valuable to only a few wildlife species (fig. 22).

Subtidal sediment deposition also creates navigation problems and increases flood frequency. Sediments deposited in the riverine parts of the estuary reduce the cross sectional area of the channel and thus increase flood water velocity and height. The resultant higher water velocity and height increases bank and dike erosion, and flooding of adjacent land.

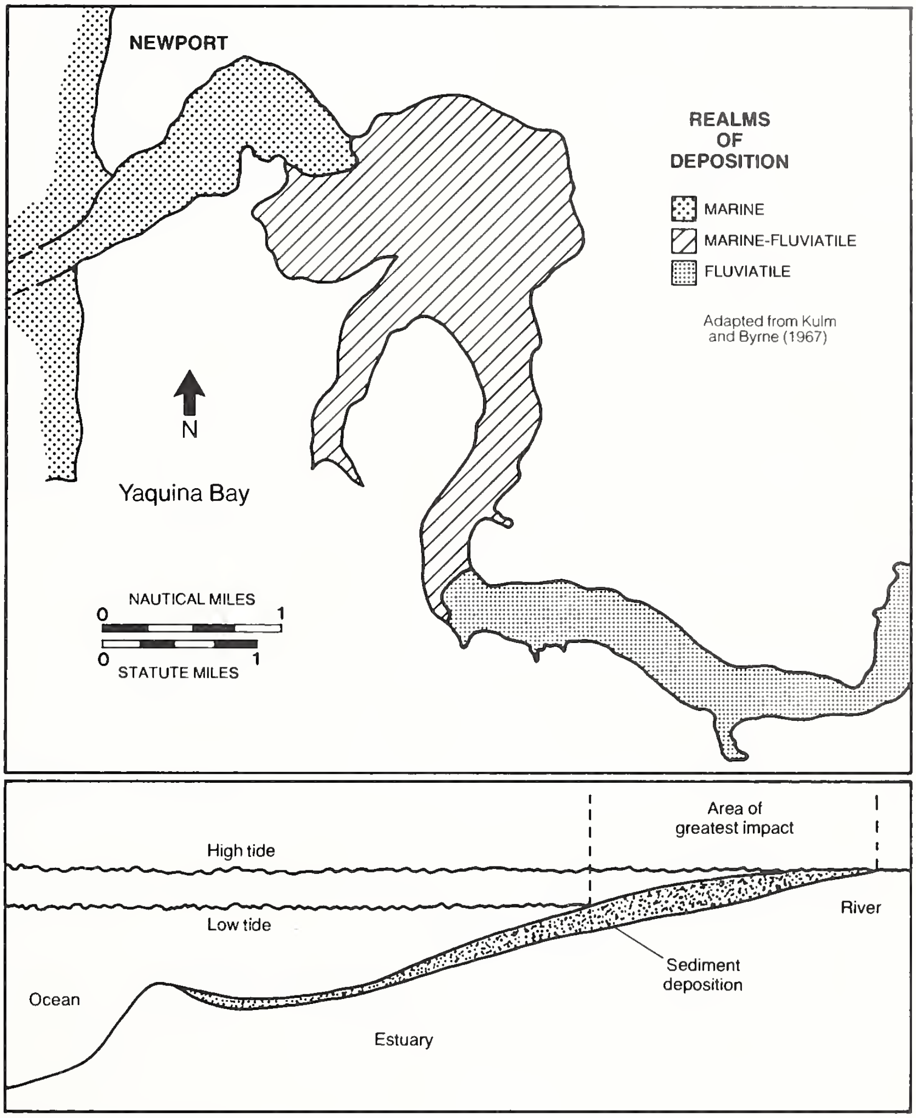


Figure 21—When river water reaches the estuary, currents are rapidly dissipated and suspended sediment settles out, reducing the tidal prism.

As shoals develop from sediment deposition, dredging becomes necessary to maintain navigation channels for commercial and recreational vessels (fig. 23). Channel dredging may create water quality problems, and by changing substrate particle size, changes the species composition of the shoal. Disposal of the dredged material is also a major problem. Historically, dredged material has been deposited in intertidal areas, on salt marshes, or on adjacent riparian vegetation. Dredged materials deposited in these locations reduce estuarine productivity and destroy habitat for animals that live in or adjacent to estuaries.

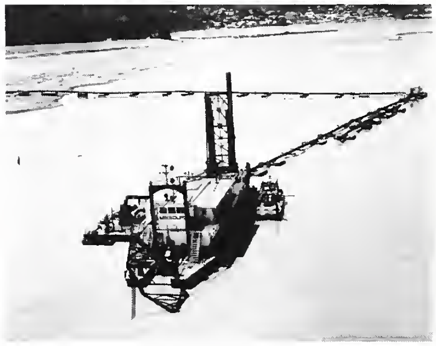


Figure 23—Increased sedimentation often necessitates dredging in order to maintain navigation routes.

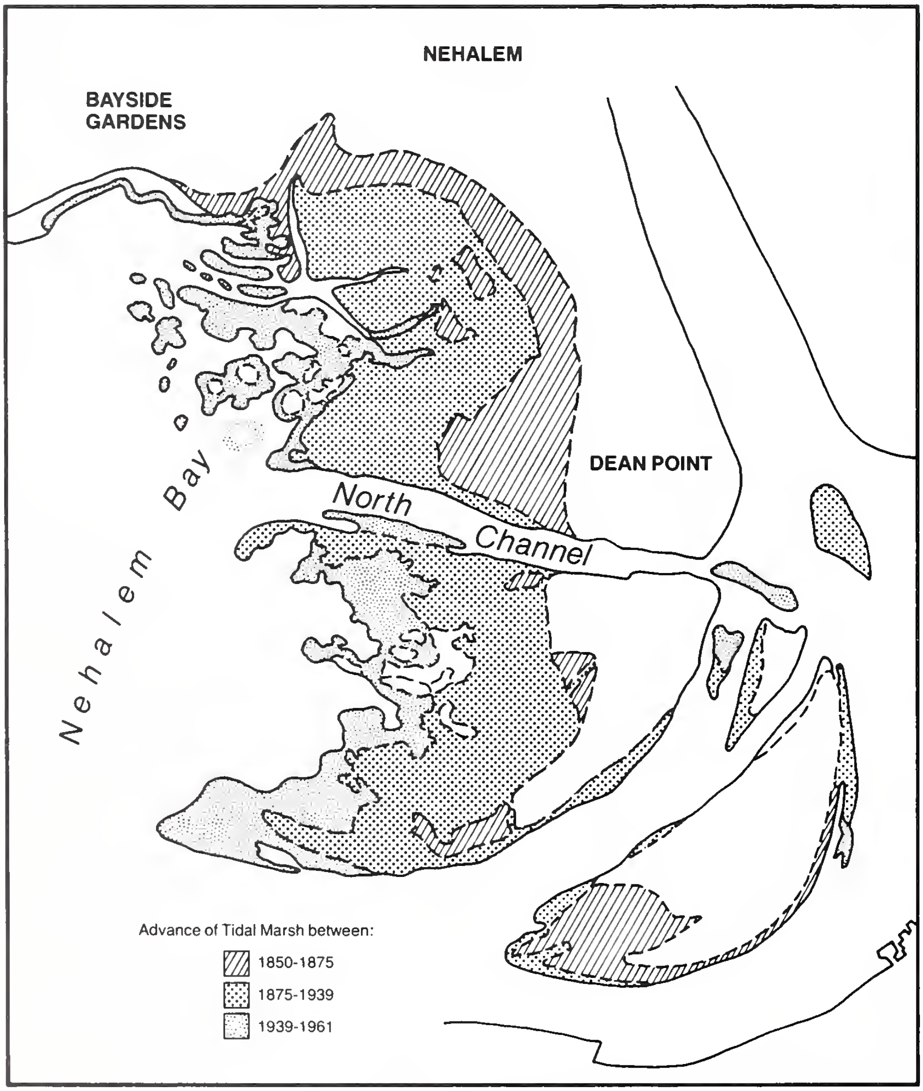


Figure 22—Marsh expansion in Nehalem Bay, Oregon (adapted from Johannessen 1964).

Water Chemistry

When a substantial area of a watershed is logged, patterns of freshwater inflow to the estuary are altered. Removal of forest vegetation results in higher peak stream discharges. The increase of freshwater into the estuary can alter salinity, dissolved oxygen, and possibly temperature and pH, while the suspended material, depending on its nature, may absorb or reflect the sun's energy which in turn affects both water and sediment temperature.

Sediments with high organic content, such as eroded forest soils, are capable of seriously reducing the dissolved oxygen content of estuarine water. Frankenberg and Westerfield (1969) found that resuspended sediments can remove 535 times their own volume of oxygen from water. Thus, dredging can cause severe though temporary water quality problems. Also, turbidity from suspended sediments reduces light penetration and retards oxygen production by estuarine plants (fig. 19), particularly microflora (Perkins 1974, Pomeroy and Stockner 1976). Because unpolluted estuaries often experience borderline oxygen concentrations, induced changes in biological or chemical oxygen demand can cause mobile species to leave or to avoid the estuary and may cause massive mortality of less mobile organisms (Odum 1970).

These factors, when combined, interfere with the feeding, movement, spawning and growth of a multitude of estuarine species. The salinity tolerance of a given species will vary with temperature and, similarly, significant changes in temperature can alter the biota of an estuary.

Table 2—Relative comparison of characteristics of four types of pesticides that cause hazards to aquatic systems (Edwards 1977) 1/

	PESTICIDES			
CHARACTERISTICS	Organochlorines	Organophosphates	Carbamates	Phenoxy herbicides
High toxicity to aquatic fauna	+ + +	+ +	+ +	+
Solubility	+	+	+	+ + +
Potential for uptake & bioconcentration	+ + +	+	+	+ +
Persistence in aquatic systems	+ + +	+	+	+ +
Heavy usage on or close to water	+ + +	+ + +	+ +	+ + +

1/ This table shows a relative comparison of the degree to which these four pesticide types possess the listed characteristics: + + + = high degree, + + = moderate degree, + = low degree.

Introduced Chemicals

Hydrologic and geologic characteristics of estuaries allow them to function as nutrient traps, or sinks, causing essential elements such as phosphorus and nitrogen to be concentrated and recycled (Odum 1970). Unfortunately, the same features which concentrate nutrients in any estuary may also collect pollutants (Cameron and Pritchard 1963).

Herbicides, insecticides, and rodenticides used in silviculture, and other chemicals used in road surfacing, are toxic materials with the potential to alter estuarine habitats and affect wildlife. The most frequently used pesticides are usually applied by aerial spray, and if inadvertently applied directly to the water produce the most pronounced pollution problems (Edwards 1977, Newton and Norgren 1977). These chemicals are most often applied in the drainage basin or adjacent to the estuary and may be carried into the estuary. These same chemicals may also enter the water ways as a result of accidents during transportation to the use area.

Chlorinated hydrocarbon pesticides and more recently organophosphate pesticides have been applied to forests for insect control, and phenoxy herbicides have been used to control vegetation. These types of pesticides have widely varying characteristics as hazards in aquatic systems. Edwards (1977) displayed some of these relationships in tabular form (table 2).

Chlorinated hydrocarbons, although their use has been significantly reduced in the past decade, pose the most serious chemical threat in aquatic systems. These insecticides transfer up the food chain and concentrate in higher organisms. This occurred particularly with the chlorinated hydrocarbons DDT and Endrin 1/.

1/ Commercial pesticide.

Many animals, including fish and oysters, have the ability to remove organochlorides present in water at sublethal concentrations and store them in their fatty tissues (Bell 1973, Odum 1970). During periods of stress the fat is metabolized and the pesticide released into the blood stream. This may result in reduced reproductive rates, poor survival of offspring, or actual direct mortality of adults.

DDT was detected in organisms in nearly all trophic levels of the estuarine environment (Odum 1970, Odum et al. 1969). The process of biomagnification of DDT results in concentration of this chemical in aquatic organisms and in birds and mammals (table 3). Because of this biomagnification process, the accumulation of chlorinated hydrocarbons such as DDT in body tissues seriously impacted top predators in the estuary such as the bald eagle, great blue heron, osprey, and others that consumed large quantities of contaminated prey. From east coast estuaries, Ohlendorf et al. (1974) collected 209 eggs of birds in the families Anhingidae (anhingas), Ardeidae (herons) and Threskiornithidae (ibises). Pesticide analysis of the egg shells showed detectable levels of DDT in 24 percent, DDE in 100 percent, PCB in 76 percent, and Dieldrin in 18 percent of the total sample.

Organophosphate insecticides have now largely replaced the chlorinated hydrocarbons. These are generally, but not always, less toxic to aquatic organisms (Bell 1973). Some, such as EPN[1] and malathion [1], have a strong synergistic effect, that when combined, have an increased toxicity of 50 times their independent potential (Bell 1973).

Organophosphates usually break down in water in less than a year and some in a few days (table 4). Their degradation is slower in cold water; therefore, they are more hazardous to aquatic animals in coldwater systems. They are transported through the ecosystem in the same manner as chlorinated hydrocarbons until they are metabolized. Current research at Huxley College of Environmental Studies, Western Washington University, has shown that bobwhite quail exposed to sublethal dosages of the organophospate chemical methyl parathion exhibit disturbances in tonic immobility, a behavior of probable significance as a predator avoidance response (Kendall et al. 1982). Such tests have not yet been applied to estuarine bird species.

[1] Commercial pesticide

Table 3—An example of food chain concentration of a persistent pesticide, DDT (Odum 1970)

	ppm [1] DDT residues
Water	0.00005
Plankton	0.04
Silverside minnow	0.23
Sheephead minnow	0.94
Pickerel (predatory fish)	1.33
Needlefish (predatory fish)	2.07
Heron (feeds on small animals)	3.57
Tern (feeds on small animals)	3.91
Herring gull (scavenger)	6.00
Fish hawk (osprey) egg	13.8
Merganser (fish-eating duck)	22.8
Cormorant (feeds on larger fish)	26.4

[1] Parts per million (ppm) of total residues, DDT + DDD + DDE (all of which are toxic), on a wet weight, whole organism basis.

Herbicides are widely used in silviculture. They are generally less toxic to animal life than insecticides, but can cause negative effects under certain circumstances (Woodward 1979, Woodward and Mayer 1978). The phenoxy herbicides 2,4-D and 2,4,5-T have been the most commonly used herbicides in the procedures involved with reforestation of cutover forest lands (Dost 1978, Thut and Haydu 1971).

Newton and Norgren (1977) stated that fish are the most sensitive animals to direct contamination of 2,4-D. In addition, laboratory application of 2,4-D showed a reduction in growth of estuarine vegetation including phytoplankton and algae (Reish et al. 1978).

The herbicide 2,4,5-T is more toxic to fish than any other animal, but is not considered a major problem in aquatic systems. It may cause malformation in mice embryos, but this question is still unanswered (Newton and Norgren 1977). A complication associated with the use of 2,4,5-T is that the contaminant TCDD can be present in pesticide products containing 2,4,5-T. The amount of TCDD in 2,4,5-T is controlled by the manufacturer to have less than 1.6×10^{-6} oz of TCDD per pound of phenoxy acid equivalent (0.1 ppm) (Newton and Norgren 1977). Miller et al. (1973) found, however, that trout exposed four weeks to 0.22×10^{-12} oz of TCDD per week in food suffered 100 percent mortality. These authors also found that death occurred in young coho salmon within 10 to 80 days if they were exposed for short periods (24 to 96 hours) to concentrations of TCDD in water at any level greater than 0.81×10^{-9} oz/oz of body weight. The impacts were irreversible even when the fish were removed from exposure after 24 to 96 hours. Isensee and Jones (1975) determined that organisms exposed to TCDD accumulated concentrations substantially greater than that of water. Personal communication from Norris (1977), reported in Newton and Norgren (1977), stated that the no-effect concentration of TCDD in water for coho salmon was between 0.05 and 0.005 parts per trillion. The problem with TCDD, however, might be short lived since 2,4,5-T has recently been banned for use in forest spraying.

Table 4—Summary of effects of aerial application of chemicals on water quality (adapted from Newton and Norgren, 1977)

Practice	Chemical used	Pollutant pattern	Duration of measurable pollution	Group most likely to be affected by pollution if any
Fertilization				
Chemical	Urea	Brief elevation of urea and low-level ammonium concentrations. Slight later elevation of nitrate.	Urea limited to immediately after application. Some elevation of nitrate from first fall rains after dry summer.	None known. Low possibility of injury to fish from NH_3 in warm water of high pH.
	Phosphorus	Brief elevation of phosphate concentration.	Limited to flooding runoff period.	None known.
Forest site preparation				
Chemical	Amitrole	Spike concentration*.	1-7 days.	None known.
	Ammonium ethyl carbamoyl phosphonate	"	"	"
	Atrazine/Simazine	"	"	"
	Dalapon	"	"	"
	Picloram	Spike concentration*, followed by very slight contamination in runoff or seepage	Spike is brief. Seepage may continue several months in range ≤ 5 ppb.	Irrigation water users (potatoes, tobacco, legumes).
	Phenoxys	Spike concentration*.	1-7 days	None known.
Scarification & Chemical	2,4,5-T	Turbidity plus chemical associated with silt.	During storm flow, as long as soil is devegetated.	Aquatic systems, potable users.
	Atrazine	"	Storm flow only, as long as soil is devegetated. Atrazine prolongs period of exposed soil.	"
Fire Plus Chemical	2,4,5-T and/or Dinoseb	Mild turbidity. Spike* of herbicide.	Storm flow only until site revegetates.	None to severe on fish spawning beds.
Insect control				
Chemical	Carbaryl	Spikes* in many streams coalesce into prolonged river pattern of low concentration.	1-7 days in feeder streams; 1-3 days longer in river.	Aquatic insects; effects no more than 2 weeks. Non-cumulative.
	Diazinon	"	"	None known.
	Disulfoton	"	"	Aquatic insects; effects no more than 2 weeks, non-cumulative.
	Endosulfan	Spikes* in many streams coalesce into prolonged pattern of low concentration in rivers; persistent chlorinated hydrocarbon may appear in very low concentrations later.	Persistent. May be problem with food chain species for extended period.	Fish extremely sensitive. Also aquatic insects. Impact likely even with buffer strips.

Practice	Chemical used	Pollutant pattern	Duration of measurable pollution	Group most likely to be affected by pollution if any
	Fenitrothion	Spikes* in many streams coalesce into prolonged river pattern of low concentration.	1-7 days in feeder streams; 1-3 days longer in river.	Possible aquatic insects, low impact unless applied directly to water.
	Guthion	Spike* in many streams coalesce into prolonged river pattern of low concentration.	1-7 days in feeder streams; 1-3 days longer in river.	Aquatic insects very sensitive – impact likely, but brief even with narrow buffer strips.
	Lindane	Not used aerially; not found in water.	None.	None.
	Malathion	Spikes* in many streams coalesce into prolonged pattern of low concentration in rivers.	1-7 days in feeder streams; 1-3 days longer in rivers.	Aquatic insects very sensitive, some impact likely, but brief, without buffer strips.
	Phosphamidon	Spikes* of low concentration in many streams coalesce into prolonged pattern of low concentration in rivers.	"	Aquatic insects if water sprayed directly.
	Trichlorfon	"	"	"
Rodent control				
Seed coat	Endrin	Brief spike*, very low maximum.	Persistent, but levels too low for toxic hazard.	None known.
Herbicide	Triazines, 2,4-D, Dalapon	Brief spike*.	1-7 days.	None known.

*"Spike" concentrations are defined as those which diminish to less than ten percent of maximum within 48 hours.

Effects of Forest Activities in Estuaries

Landfills, log storage, and shoreline tree removal are the most common forest activities located in or adjacent to estuaries. These activities induce some of the same physical changes as do watershed activities, but with lesser magnitude because they usually occur in a more localized area.

Landfills

Landfills may be initiated for several purposes in relation to forestry activities. The most common purpose is to facilitate access to adjacent timber lands. Other reasons include log handling and storage as well as transport of equipment and materials (fig. 24).

The most direct and obvious alterations of the physical environment in estuaries are produced by landfills. For example, each mile of road built in an estuary with a 16 ft running surface, 4 ft shoulders and 1½ to 1 shoulder slopes on an 8 ft fill covers a minimum of 6 acres. In deep water, even more acreage would be covered. By completely and rapidly covering existing substrates, and by raising the ground elevation, a landfill totally removes the area from estuarine productivity and reduces the tidal prism. During the filling activities and for some time following, the introduced material, as a result of wave action, changing tidal currents, rain, and wind, increases sediment transport and deposition in the surrounding area. This may increase suspended solids and reduce light penetration in a significant portion of the estuary.

Figure 24—Landfills on intertidal areas, whether for disposal of dredge spoils, road building, or log handling and storage, destroy estuarine habitat.

Roads constructed with fills intruding on estuary margins and across salt marshes to access forest land for management purposes not only remove acreage from production but also may create dikes which interfere with nutrient and detritus interchange between open water and vegetated areas (fig. 25). When salt marshes are diked by road fills, water interchange is limited by the number, size, and distribution of drainage structures. If the drainage structures are too small, too infrequent, or in disrepair, the marsh area enclosed by the dike will receive the same amount of freshwater from upland sources but the flow of saltwater into that area will be reduced. This causes a gradual shift in community compostition in the diked areas to plants more adapted to freshwater and a reduction in the amount of chemical nutrients received from the ocean. The dike may also prevent the plant material, detritus, and nutrients produced by the marsh from entering the estuarine food web.

Roads built along the estuary perimeter also increase the chance of an accidental introduction of toxic materials to the estuary. This might include spills of petroleum products and those of a highly acidic or basic character that originate from wood products processing plants.

Chemicals spilled accidentally are usually highly concentrated and locally detrimental to plants and animals. Although the chemicals may affect only a localized area, the potential exists for pollution of a larger area. Chemicals spilled on land may be adsorbed by eroding soil particles or suspended in water and be transported into adjacent estuarine water. Oil spilled directly into the river or estuary is extremely difficult to contain because of constant water movement. More soluble chemicals generally prove impossible to contain.

Spilled oil adversely affects birds by contaminating their feathers—hypothermia is the probable result, and

Figure 25—Roads built across estuarine salt marshes can interfere with water interchange and have severe impacts on the marsh ecosystem.

damages the gills or other soft tissue of invertebrates exposed to the oil as the tide recedes. Animals living within the water column, or subtidally would not be significantly affected unless the spill included soluble chemicals. Dissolved chemicals can be expected to have more adverse impacts on the soft tissues of invertebrates and fishes but less effects on birds and mammals.

Landfills for log storage and handling often are located in salt marshes totally destroying the production capability of the marsh areas impacted. Unprotected banks are sometimes subject to severe erosion that leads to deposition in other places. Surface compaction caused by operation of heavy equipment on these decking areas, combined with rainfall, can result in a significant amount of runoff that may carry suspended sediments as well as organic leachates and wood fibers into the estuary. The close proximity of the landfill to the estuary makes control of inflow of these deleterious materials difficult.

Log Rafting and Storage

The transport of logs via waterways is historic. A part of this history includes the rafting of logs in estuaries and storage along shorelines. Embayed estuaries in particluar have provided protected water storage for log rafts since logging began in the Pacific Northwest (fig. 26). The potential environmental problems associated with log storage are numerous (table 5). Some are unavoidable; others can be mitigated to some extent by various handling procedures, location selection, storage duration, and other management decisions (Hansen et al. 1971).

Even though log rafting is not as prevalent as it once was, there are still hundreds of acres of estuaries where log rafts continue to introduce bark, debris, and leachates, and physically occupy otherwise productive mudflats. In addition to occupying a location, log rafts and their associated pilings are energy dissipators that slow water velocity and thus increase the rate of sediment deposition in the area (Toews and Brownlee 1981).

Figure 26—The rafting and storage of logs in estuarine areas is a common practice in the Pacific Northwest that creates numerous problems for estuarine wildlife.

Table 5—Adverse impacts of intertidal estuarine log storage (adapted from Toews and Brownlee 1981).

IMPACT	DEGREE OF IMPACT Primary	Secondary	SIGNIFICANCE
Shading	Decreased primary production by microalgae (planktonic and benthic), macroalgae, eelgrass.	Altered food chains.	Less significant.
Grounding, abrasion	Destruction of plants, epifauna, infauna.	Destruction of food chains, lost "living space."	Highly significant.
Reduced current and wave action	Increased sediment deposition, increased fines, debris retention, decreased sediment flushing.	Altered food chains, lost living space, chemical changes.	Significant.
Leachates, debris	Toxicity (biological oxygen demand).	Decreased or altered flora and fauna.	Highly significant.
Towboat prop. wash in approaches	Disturbance and destruction of flora and fauna.	Decreased production. Altered communities.	Highly significant.

Log rafts block sunlight that normally strikes the water column and substrate of shallow intertidal zones (Zegers 1978). The amount this shading reduces primary productivity depends on the size of the rafts and the duration of storage over one location. If log rafts are stored in intertidal shallows such that they rest on the bottom at low tide, several physical impacts result (fig. 27). These include sediment compaction, grinding, and churning (Pease 1974, Smith 1977, Zegers 1978). Propeller wash caused by tugboats handling logs in shallow water is another source of substrate alteration (Towes and Brownlee 1981).

During handling, and as a result of water motion, rafted logs are scraped and bumped together, resulting in bark loss and deposition in the estuary (Toews and Brownlee 1981). The logs release large amounts of soluble organic compounds (leachates) into the water (Graham 1970, Hansen et al. 1971, Pease 1974, Schaumburg 1973). The bark accumulation and the leachates increase benthos oxygen uptake, decrease dissolved oxygen, lower pH, increase volatile solids, increase toxic sulfide compounds, increase water coloration, and change the physical composition of the substrate (Buchanan et al. 1976, Pease 1974, Smith 1977).

Bark build-up on the bottom of bays and channels usually occurs at log dumping sites, but is occasionally observed at log rafting sites which have experienced long-duration storage (McDaniel 1973). McDaniel (1973) and Pease (1974) discovered that toxicity and oxygen depletion caused by a bark layer are detrimental to the abundance and diversity of benthic fauna.

Pease (1974) and Schaumburg (1973) performed laboratory studies that demonstrated that extremely high concentrations of leachates are lethal to juvenile salmonids. Both authors reported that mortality was observed only in a closed system in which logs had been immersed for seven days. Toews and Brownlee (1981) reported that tannic acid, leached from the bark of logs, was toxic to chinook salmon fry at concentrations as low as 1.7 ppm in saltwater. Oyster larvae abnormalities occurred at concentrations as low as 1.48 ppm. Although leachates apparently do not cause direct mortality in open water areas, they may affect species behavior. Information regarding behavioral changes of fish and other species caused by sublethal concentrations of log leachates is not currently available.

Shoreline Tree Removal

Estuaries characterized by large river deltas with numerous distributory channels often have commercially valuable timber along the land/water edge. Also, open coast estuaries with steep-sloped river banks are frequently characterized by forested shorelines. The forest vegetation in these environments binds the soil and provides cover for terrestrial animals that use estuaries. Trees adjacent to the estuary contribute some detritus in the form of leaf or needle fall, and also are important perches for predatory or colonial birds such as eagles, herons, and kingfishers. In some areas, they are heavily used by band-tailed pigeons seeking the brackish water in estuary tide channels. Trees that fall on an intertidal flat also provide habitat for smaller birds and mammals. When a tree falls into the estuary, the fine branches help to catch and retain filamentous algae and other drifting organic materials that provide substrate for benthic plants and animals. Ultimately, the fine branches and main trunk of the tree succumb to the shredders and burrowers who use them for food and shelter.

Figure 27—Log rafts allowed to rest on the bottom at low tide compact and scour sediments and smother estuarine animals.

Removal of these large trees during timber management activities reduces the overall productivity of the estuary by reducing leaf and litter fall, depriving the estuary of substrate, and by removing feeding and resting habitat for birds and small mammals (fig. 28). As an example, Woodcock (1902) found approximately 10 pairs of bald eagles residing in the Yaquina Bay area of Oregon. Meslow (1982) reports that in this area today, only one nest site is known and it has not been productive during the past two years. Human encroachment and loss of nest trees appear to be the primary factors responsible for this decline.

Figure 28—Removal of vegetation around the shoreline of an estuary eliminates perching, roosting, and nesting sites for birds, and destroys cover for terrestrial wildlife that feed in the estuary.

Discussion

The estuary is a complex and dynamic aquatic ecosystem. Charged by oceanic and continental forces, the estuary undergoes tremendous physical and chemical changes on a daily as well as a seasonal basis. Within this complex and changing system, many species of plants and animals have evolved that capitalize on sunlight, nutrients, and space to create valuable resources.

Forest-management related activities within the estuary, on the periphery of the estuary, or those further removed but within the watershed draining into the estuary, can all impact estuarine habitats and the wildlife that depend on them. The accelerated influx of sediments and chemicals into the aquatic system is the primary cause of estuarine change that can be related to forest activities.

Since sediment and chemicals are transported throughout the estuarine system, the impacts on habitats are usually widespread. Because they are widely dispersed, short-term effects are difficult to measure but result primarily in an interruption in the quantity and quality of food available to first level consumers. If severe, these effects are carried up through the food chain and impact animals at the higher trophic levels. Recovery from these short-term impacts usually occurs quite rapidly once the sediment and chemical transport into the estuary is reduced.

Accelerated sediment deposition over extended periods creates long-term effects that are more serious. These impacts involve a reduction in the overall tidal prism, an increase in elevation of the estuary floor, and substantial changes in the plant and animal communities that occupy these habitats.

Impacts from activities that occur within the estuary usually are more concentrated in location but also tend to be long-term. Road construction, channel dredging for navigation, and landfills for log decking or storage, not only destroy the estuary at the site of the activity, but may also alter stream flows, tidal currents, and wind patterns that are all vital elements of the estuarine ecosystem. Wet log storage impacts significant acreages in estuaries through shading effects, bark deposition, toxins leaching into the water from rafted logs, and soil compaction at low tides.

Those occurrences that cause effects of a more ephemeral nature, such as accidental spills of chemicals or fuels, can have severe localized impacts but are generally of less consequence. They are sporadic in occurrence and the effect normally will be short-lived because the toxic material eventually will be flushed from the estuary by natural forces.

The effects of forest-management activities on a specific estuary are often diffuse and difficult to quantify. It is evident, however, that in many Pacific Northwest estuaries significant physical and biological changes have taken place and the primary factors contributing to these changes are the activities that have taken place in the forested watersheds above the estuaries.

Management Considerations

The estuaries of Western Oregon and Washington vary greatly in size, physical composition, and biological characteristics. There is a wide diversity in the kinds and intensity of activities affecting these estuaries. Many activities that have significant impacts on estuaries occur in watersheds far removed from the estuary itself. Developing comprehensive recommendations for the protection of estuarine resources is further complicated by the fact that forest practices may be just one of several upstream activities contributing to the degradation of the estuary.

Only those activities with direct on-site applicability to estuaries such as road design, location, construction, and maintenance in estuarine areas; log rafting; shoreline buffer strips; and herbicide applications will receive further discussion here. For information concerning mitigation of impacts resulting from forest management activities in the watersheds above the estuary, the reader is referred to chapter 4 (Riparian Zones and Freshwater Wetlands) and chapter 10 (Salmonids). The suggestions and considerations presented in those chapters for the protection of riparian zones and salmonid habitats will also serve to mitigate impacts on estuarine areas accruing from forest management activities such as forest road construction, timber harvest scheduling, unit design and layout, and harvest methods.

Roads

Location and Design

Considerations

Prevent isolation of salt marshes by road fills; insure continued interchange of fresh and salt water; minimize acreage covered by road fills.

Options

- Build in locations where river or stream channels will not be affected;
- Circumvent tidal marshes where possible;
- Provide numerous drainage structures for tidal interchange and locate these where intertidal channels are being intercepted;
- Install the drainage structure so that the bottom is at the same elevation as the bottom of the channel being crossed;
- Insure that drainage structures are constructed of materials resistant to corrosion by saltwater, decay, and boring animals;
- Strongly discourage installation of tide gates;
- Use materials that withstand a steep angle of repose;
- Use minimum road widths;
- Minimize road length.

Construction

Considerations

Minimize sediment production; prevent cutbank failures; minimize the chance of debris avalanches; reduce the amount of sediment entering the estuary.

Options

- Use fill materials on subtidal and intertidal areas that are resistant to erosion;
- Schedule construction activities during the driest season of the year;
- Complete construction as rapidly as possible;
- Provide adequate surfacing to protect the subgrade;
- Surface the road and seed, mulch, and fertilize road shoulders and fill slopes as soon as possible after construction;
- Never leave partially constructed roads over winter;
- Use non-toxic surfacing materials;
- Use bank stabilizing techniques in wet areas;
- Use proper cut-bank slope for type of soil encountered;
- End-haul excavated materials to a safe upland disposal site and protect from erosion;
- Minimize the use of heavy equipment in wet areas.

Maintenance

Considerations

Reduce sediment generated from the road surface; prevent sediment from entering the estuary.

Options

- Construct hard surfaced roads wherever practical;
- Keep sufficient surfacing on the road to eliminate "pumping" of fines up from the subgrade;
- Keep road crowned or sloped so surface runoff is directed onto vegetated road shoulders;

- Keep road shoulder and fill slope vegetation healthy by fertilizing and by minimizing application of herbicides;
- Maintain ditches and revegetate immediately after removing bank slough;
- Periodically inspect riprap and repair as necessary to prevent washouts;
- Direct any diverted surface drainage to stable vegetated areas for filtration;
- Install energy dissipators at flume outfalls to prevent erosion during storms.

Chemicals and Fuel

Herbicides and Pesticides

Considerations

Reduce herbicide and pesticide influence on estuary productivity; minimize possibility of accidental spills.

Options

- Minimize the use of chemicals;
- Follow Oregon and Washington Forest Practices Rules for proper application;
- Emphasize vehicle safety and driver training when transporting or applying herbicides;
- Preplan transportation routes, parking, and working areas to minimize possibility of accidents and spills;
- Use the herbicide and pesticide having the least impact on non-target plants and animals consistent with forestry objectives;
- Use only properly registered chemicals;
- Follow label directions precisely.

Fuel

Consideration

Reduce or eliminate the influence of fuel spills on estuarine resources.

Options

- Require fuel trucks using forest roads to have frequent safety checks;
- Allow only experienced drivers to drive fuel trucks on hazardous roads;
- Plan fuel deliveries for periods of least traffic;
- Refuel in areas away from aquatic systems.

Estuary Margin Buffer Strips

Wildlife Food and Cover

Considerations

Preserve perch and nest trees for predatory, colonial nesting, and passerine birds; provide for future perch and nest trees; and provide future large woody debris to the estuary perimeter.

Options

- Leave large trees along estuary perimeter as perches or nesting sites and to contribute organic detritus to the food web;
- Reforest estuary margins with conifers capable of withstanding wind stress;
- Keep slash fires and herbicides out of the protection strip;
- Leave large downed trees that have fallen into the estuaries to provide habitat for both vertebrate and invertebrate species inhabiting intertidal estuarine areas;
- Leave a protective vegetation strip wide enough to provide cover and travel ways for mammals as well as to minimize effects of blowdown.

Bank Stability

Consideration

Protect vegetation to provide bank stability.

Options

- Leave a protective vegetation strip wide enough to provide bank protection;
- Keep slash fires and herbicides out of the protection strip;
- Leave large downed trees to slow water velocity and stabilize channel margins.

Log Rafting

Location

Considerations

Minimize water quality problems; reduce damage to benthic organisms; prevent substrate compaction and siltation.

Options

- Use upland log storage sites wherever possible;
- Bundle logs to increase the capacity of rafting areas;
- Keep the size of the rafting area to a minimum;
- Locate in areas with good water circulation but away from strong currents;
- Locate away from known clam beds;
- Locate where water depths are sufficient to float log bundles during all tidal regimes, and tugs used in handling will not disturb the substrate.

Debris and Toxin Control

Considerations

Reduce debris entering the estuary; minimize the effect of toxins leached from stored logs.

Options

- Bundle logs to reduce bumping and bark loss;
- For log dumping, use easy-let-down devices to reduce bark separation and other debris;
- Keep duration of "in water" storage to a minimum;
- Dispose of bark and debris from the unloading area at upland sites away from the estuary.

Erosion and Mass Movement

Bed Load Movement

Considerations

Reduce dredge spoil erosion; minimize the chance of debris avalanches associated with road construction or in-unit failures.

Options

- Deposit dredge spoils on upland sites wherever possible;
- Locate dredge spoils where wind, wave, and river current erosion will be at a minimum;
- Retain large in-stream debris to help retain bed load in upper channel areas;
- Install trash barriers to prevent road fill culverts from plugging up;
- Patrol vulnerable road systems during storms.

Suspended Sediment

Consideration

Prevent or reduce sediment entering estuarine waters.

Options

- Emphasize erosion control in all construction activities including grass seeding, mulching, etc.;

- Protect stream channels from physical damage caused by log removal or other disturbance factors;
- Utilize settling basins in conjunction with deposition of dredge spoils.

Habitat Improvements

Tidal Prisms

Considerations

Restore tidal prisms lost to road fills, land fills, or dredge spoil dumping.

Options

- Return to the estuary an amount of intertidal surface area and volume equivalent to the volume and area lost in the road, landfill, or dredge spoil site, and store removed material at a stable upland site;
- Select tidal areas as far up-channel (away from the ocean) as possible to increase benefits of tidal prism replacement.

Piling Removal

Consideration

Reduce sedimentation and water quality degradation caused by log raft pilings.

Options

- Pull or saw off abandoned pilings at the mud line;
- Remove pilings as soon as they lose their utility.

The suggestions in this chapter as well as those in chapters 4 and 10 cannot be all inclusive nor apply in all situations. In some circumstances the suggestions may seem in opposition to one another. Whenever activities being planned seem unaddressed by these suggestions or if there are apparent conflicts, consultation should be initiated with fisheries and wildlife biologists to determine how the project can best be facilitated without adversely affecting the aquatic or estuarine resources.

References Cited

Bahr, L. M.; Lanier, W. P. The ecology of intertidal oyster reefs of the south Atlantic Coast: a community profile. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services; 1981; FWS/OBS-81/15. 105 p.

Bascom, W. Coastal water research project. Biennial Rep. 1979-80. Long Beach, CA: Southern California Coastal Water Research Project: 1980. 363 p.

Bell, M. C. Fisheries handbook of engineering requirements and biological criteria. Portland, OR: U.S. Army Corps of Engineers, North Pacific Division, Fisheries-Engineering Research Program; 1973. 450 p.

Bottom, D.; Forsberg, B. The fishes of Tillamook Bay. Project F-100-R. Portland, OR: Oregon Department of Fish and Wildlife; 1978. 56 p.

Buchanan, D. V.; Tate, P. S.; Moring, J. R. Acute toxicities of spruce and hemlock bark extracts to some estuarine organisms in southeastern Alaska. J. Fish. Res. Bd. Can. 33(5): 1188-1192; 1976.

Burt, W. V.; McAlister, W. B. Recent studies in the hydrography of Oregon estuaries. Portland, OR: Fish Commission of Oregon; Research Briefs. 7(1): 14-27; 1959.

Cameron, W. M.; Pritchard, D. W. Estuaries. In: Hill, M. N., ed. The sea. New York, NY: John Wiley and Sons; 1963: 306-323.

Carriker, M. R. Ecology of estuarine benthic invertebrates: a perspective. In: Lauff, G. H., ed. Estuaries. Pub. No. 83. Washington, DC: American Association for the Advancement of Science; 1967: 442-487.

Cederholm, C. J.; Reid, L. M.; Salo, E. O. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. In: Proceedings of a conference, salmon-spawning gravel: a renewable resource in the Pacific Northwest? 1980 October 6-7; Seattle, WA: University of Washington, College of Fisheries; 1981. 35 p.

Davis, H. C.; Hidu, H. Effects of turbidity-producing substances in sea water on eggs and larvae of three genera of bivalve mollusks. Veliger. 11: 316-323; 1969.

Davis, M. W.; McIntire, C. D. Production dynamics of sediment-associated algae in two Oregon estuaries. Estuaries. 4(3): 301; 1981.

Dost, F. N. Toxicology of phenoxy herbicides and 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin. Corvallis, OR: Oregon State University, Department of Agricultural Chemistry and Environmental Health Sciences Center; 1978. 70 p.

Edwards, C. A. Nature and origins of pollution of aquatic systems by pesticides. In: Proceedings, pesticides in aquatic environments, a symposium for the International Congress of Entomology. 1976 August 22; Washington DC. New York, NY: Plenum; 1977: 11-38.

Eilers, H. P., III. Plants, plant communities, net production and tide levels: the ecological biogeography of the Nehalem salt marshes, Tillamook County, Oregon. Corvallis, OR: Oregon State University; 1975. 368 p. Dissertation.

Forsberg, B. O.; Johnson, J. A. ; Klug, S. M. Identification, distribution, and notes on food habits of fish and shellfish in Tillamook Bay, Oregon. Job Compl. Rep. Tillamook, OR: Oregon Department of Fish and Wildlife, Research Section; 1977. 117 p.

Frankenberg, D.; Westerfield, C. W., Jr. Oxygen demand and oxygen depletion capacity of sediments from Wassaw Sound, Georgia. Athens, GA: Bull. Georgia Academy of Science: 160-176; 1969.

Gerke, R. J.; Kaczynski, V. W. Food of juvenile pink and chum salmon in Puget Sound, Washington. Olympia, WA: Washington Department of Fisheries; 1972; Tech. Rep. No. 10. 21 p.

Gonor, J. J.; Strehlow, D. R.; Johnson, G. E. Ecological assessments at the North Bend airport extension site. Part I of Tideland Mitigation Resources Planning Goal. Rep. to Oregon Department of Land Conservation and Development. Corvallis, OR: Oregon State University, School of Oceanography. 1979.

Gosselink, J. Tidal marshes – the boundary between land and ocean. Baton Rouge, LA: Louisiana State University, Center for Wetland Resources. U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services; 1980; FWS/OBS-80/15. 12 p.

Graham, J. L. Pollutants leached from selected species of wood in log storage waters. Corvallis, OR: Oregon State University; 1970. 45 p. Thesis.

Green, J. The biology of estuarine animals. 3d ed. Seattle, WA: University of Washington Press. 1975. 401 p.

Gresswell, S.; Heller, D.; Swanston, D. Mass movement response to forest management in the central Oregon Coast Ranges. Resour. Bull. PNW-84. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 26 p.

Hansen, G.; Carter, G.; Towne, W.; O'Neal, G. Log storage and rafting in public waters, a task force report. Olympia, WA: Washington Department of Ecology, Pacific Northwest Pollution Control Council; 1971, 56 p.

Hedgpeth, J. W. Aspects of the estuarine ecosystem. In: A symposium on estuarine fisheries: American Fisheries Society Spec. Publ. No. 3; presented at the 94th annual meeting of the American Fisheries Society; 1964 September; Atlantic City, NJ.: 1966: 3-11.

Hedgpeth, J. W.; Obrebski, S. Willapa Bay: a historical perspective and a rationale for research. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services; 1981; FWS/OBS-81/03. 52 p.

Herbert, D. W. M.; Alabaster, J. S.; Dart, M. C.; Lloyd, R. The effect of china clay wastes on trout streams. Int. J. Air and Water Pollution. 5(1): 56-74; 1961.

Herbert, D. W. M.; Merkens, J. C. The effect of suspended mineral solids on the survival of trout. Int. J. Air and Water Pollution. 5(1): 46-55; 1961.

Herman, S. G.; Bulger, J. B. The distribution and abundance of shorebirds during the 1981 spring migration at Grays Harbor, Washington. Seattle, WA: U.S. Army Corps of Engineers, Seattle District; 1981; Cont. No. DACW67-81-M-0936. 64 p.

Isensee, A. R.; Jones, G. E. Distribution of 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin (TCDD) in aquatic model ecosystem. Env. Sci. and Tech. 9: 668-672; 1975.

Johannessen, C. L. Marshes prograding in Oregon estuaries. Science. 146 (3651): 1575-1578; 1964.

Johnson, R. G.; Beschta, R. L. Logging, infiltration capacity, and surface erodibility in western Oregon. J. Forestry. 76(6): 334-337; 1980.

Kendall, R. J.; McAlpine, C. L.; Driver, C. J.; Thompson, R. W. Effects of methyl parathion on tonic immobility and brain acetylcholinesterase activity in bobwhite quail (*Colinus virginianus*). Proceedings 3d Annual Meeting – Society of Environmental Toxicology and Chemistry; 1982 November 14-17; Arlington, VA: Rockville, MD: Soc. of Environmental Toxicology and Chemistry. 1982.

Kulm, L. D.; Byrne, J. V. Sediments of Yaquina Bay, Oregon. In: Lauff, G. H. ed. Estuaries. Pub. No. 83. Washington, DC: American Association for the Advancement of Science; 1967: 226-260.

Lane Council of Governments. Preliminary Lane County general plan, water quality report. Eugene, OR: Lane Council of Governments and Lane Co.; 1974. 138 p.

Levings, C. D. The biology and energetics of *Eogammarus confervicolus* (Stimpson) (Amphipoda, Anisogammaridae) at the Squamish River Estuary, B.C. Can. Jour. Zool. 58: 1652-1663; 1980.

Loosanoff, V. L. Effects of turbidity on some larval and adult bivalves. In: Proceedings, fourteenth annual session – Gulf and Caribbean Fisheries Institute; Coral Gables, Florida: University of Miami; 1961: 80-94.

McDaniel, N. G. A survey of the benthic macroinvertebrate fauna and solid pollutants in Howe Sound. West Vancouver, B. C.: Fisheries Research Board of Canada, Pacific Environment Institute; 1973; Tech. Rep. No. 385. 64 p.

MacGinitie, G. E. The natural history of *Callianassa californiensis* Dana. Am. Midl. Nat. 15(2): 166-177; 1934.

Markham, J. C. A study of the animals inhabiting laminarian holdfasts in Yaquina Bay, Oregon. Corvallis, OR: Oregon State University; 1967. 62 p. Thesis.

Martin, A. C.; Zim, H. S.; Nelson A. L. American wildlife and plants. New York, NY: McGraw-Hill Book Co., Inc.; 1951. 500 p.

Meslow, E. C. Personal communication. Leader, Oregon Cooperative Wildlife Research Unit. Oregon State University, Corvallis, OR. 1982.

Miller, R. A.; Norris, L. A.; Hawkes, C. L. Toxicity of 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin (TCDD) in aquatic organisms. Research Triangle Park, NC: U.S. Department of Health, Education and Welfare, National Institute of Environmental Health Sciences; Environmental Health Perspectives; Experimental Issue No. 5; 1973: 177-186.

Morgan, A. R.; Gerlach, A. R. Striped bass studies on Coos Bay, Oregon in 1949 and 1950. Portland, OR: Oregon Fish Commission; 1950; Contribution No. 14. 31 p.

Naiman, R. J.; Sibert, J. R. Detritus and juvenile salmon production in the Nanaimo estuary: III. Importance of detrital carbon to the estuarine ecosystem. J. Fish. Res. Bd. Can. 36: 504-520; 1979.

Newton, M.; Norgren, J. Silvicultural chemicals and protection of water quality. Seattle, WA: U.S. Environmental Protection Agency, Region 10; 1977; EPA 910/9-77-036. 224 p.

Norris, L. A. Personal communication. Reported in: Newton, M.; Norgren, J. Silvicultural chemicals and protection of water quality. Seattle, WA: U.S. Environmental Protection Agency, Region 10; 1977; EPA 910/9-77-036. 224 p.

O'Connor, J. M.; Neumann, D. A.; Sherk,; J. A., Jr. Lethal effects of suspended sediments on estuarine fish. Tech. Pap. No. 76-20. Fort Belvoir, VA: U.S. Army Corps of Engineers, Coastal Engineering Research Center; 1976. 90 p.

O'Connor, J. M.; Neumann, D. A.; Sherk, J. A., Jr. Sublethal effects of suspended sediments on estuarine fish. Tech. Pap. No. 77-3. Fort Belvoir, VA: U.S. Army Corps of Engineers, Coastal Engineering Research Center; 1977. 90 p.

Odum, E. P. Fundamentals of ecology. 3d ed. Philadelphia, PA: W. B. Saunders, Co.; 1971. 574 p.

Odum, W. E. Insidious alteration of the estuarine environment. Trans. Am. Fish. Soc. 4: 836-846; 1970.

Odum, W. E.; Woodwell, G. M.; Wurster, C. F. DDT residues absorbed from organic detritus by fiddler crabs. Science. 164(3879): 576-577; 1969.

Ohlendorf, H. M.; Klaas, E. E.; Kaiser, T. E. Environmental pollution in relation to estuarine birds. In: Khan, M. A. O.; Bederka, J. P., Jr., eds. Survival in toxic environments. Patuxent Wildlife Research Center, MD: U.S. Department of the Interior, Bureau of Sport Fisheries and Wildlife; 1974: 53-81.

Pacific Northwest River Basins Commission, Puget Sound Task Force, Hydrologic Studies Technical Committee. Appendix 3: Hydrology and natural environment. In: Comprehensive study of water and related land resources, Puget Sound and adjacent waters. Vancouver, WA: Pacific Northwest River Basins Commission; 1970a. 201 p.

Pacific Northwest River Basins Commission, Puget Sound Task Force, Drainage and Land Stabilization Technical Committee. Appendix 14: Watershed management. In: Comprehensive study of water and related land resources, Puget Sound and adjacent waters. Vancouver, WA: Pacific Northwest River Basins Commission; 1970b. 201 p.

Pacific Northwest River Basins Commission, Puget Sound Task Force, Report Planning Committee. Summary report. In: Comprehensive study of water and related land resources, Puget Sound and adjacent waters. Vancouver, WA: Pacific Northwest River Basins Commission; 1971. 7 Chapters.

Page, G. W. Discussion. Presented at Coastal Ecosystems Workshop; 1978 August 29-September 1; Asilomar, CA: U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services. 1978.

Pease, B. C. Effects of log dumping and rafting on the marine environment of southeast Alaska. Gen. Tech. Rep. No. PNW-22. Portland, OR: Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1974. 58 p.

Percy, K. L.; Sutterlin, C.; Bella, D. A.; Klingeman, P. C. Descriptions and information sources for Oreogn estuaries. Corvallis, OR: Oregon State University, Sea Grant College Program; 1974. 294 p.

Perkins, E. J. The biology of estuaries and coastal waters. New York, NY: Academic Press; 1974. 678 p.

Peterson, C. H.; Peterson, N. M. The ecology of intertidal flats of North Carolina: a community profile. Slidell, LA: U.S. Department of the Interior, Fish and Wildlife Service, National Coastal Ecosystem Team; 1979; FWS/OBS-79/39. 73 p.

Pomeroy, W. M.; Stockner, J. G. Effects of environmental disturbance on the distribution and primary production of benthic algae on a British Columbia estuary. J. Fish. Res. Bd. Can. 33(5): 1175-1187; 1976.

Pritchard, D. W. What is an estuary: physical viewpoint. In: Lauff, G. H., ed. Estuaries. Pub. No. 83. Washington, DC: American Association for the Advancement of Science; 1967: 3-5.

Proctor, C. M., Garcia, J. C.; Galvin, D. V.; [and others]. An ecological characterization of the Pacific Northwest coastal region. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service, Biological Services Program; 1980; FWS/OBS-79/11 through FWS/OBS-79/15. 5 vol.

Rattray, M., Jr. Some aspects of the dynamics of circulation in fjords. In: Lauff, G. H., ed. Estuaries. Pub. No. 83. Washington, DC: American Association for the Advancement of Science; 1967: 52-59.

Reid, L. M. Sediment production from gravel-surfaced forest roads, Clearwater Basin, Washington. Seattle, WA: University of Washington; 1981. 350 p. Thesis.

Reimers, P. E. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Research Reports of the Fish Commission of Oregon, Vol. 4, No. 2. Portland, OR: Fish Commission of Oregon; 1973. 43 p.

Reish, D. J.; Kauwling, T. J.; Mearns, A. J.; [and others]. Marine and estuarine pollution. J. Water Pollution Control Federation. 50: 1424-1469; 1978.

Ricketts, E. F.; Calvin, J. Between Pacific tides. 4th ed. Stanford, CA: Stanford University Press; 1974. 614 p.

Ritchie, D. E., Jr. Gross physical and biological effects of overboard spoil disposal in upper Chesapeake Bay. NRI Spec. Rep. No. 3. College Park, MD: University of Maryland, Natural Resources Institute; 1970: 50-58.

Rogers, B. A. Tolerance levels of four species of estuarine fishes to suspended mineral solids. Kingston, RI: University of Rhode Island; 1969. 94 p. Thesis.

Schaumburg, F. D. The influence of log handling on water quality. Corvallis, OR: U.S. Environmental Protection Agency; National Environmental Research Center; 1973. 89 p.

Schrag, J. Distributions, trophic relationships, and energetics of salt marsh insect populations. In: Hoffnagle, J.; [and others]. A comparative study of salt marshes in the Coos Bay estuary. A NSF student originated study. Charleston, OR: University of Oregon Marine Biology Station; 1976; 156-160.

Schubel, J. R.; Bokuniewicz, H. J.; Gordon, R. B. Transportation and accumulation of fine-grained sediments in the estuarine environment. Spec. Rep. No. 14. Stony Brook, NY: State University of New York, Marine Science Research Center; 1978. 11 p.

Sigler, J. W.; Bjornn, T. C. Effects of chronic turbidity on feeding, growth, and social behavior of steelhead trout and coho salmon. An. Rep. Moscow, ID: University of Idaho, Idaho Cooperative Fisheries Research Unit; 1979; 28 p.

Simenstad, C. A.; Miller, B. S.; Nyblade, C. F.; [and others]. Food web relationships of northern Puget Sound and the Strait of Juan de Fuca: a synthesis of the available knowledge. EPA-600/7-79-259. Seattle, WA: University of Washington. 1979. 335 p.

Smith, J. E. A baseline study of invertebrates and of the environmental impact of intertidal log rafting on the Snohomish River delta. Seattle, WA: University of Washington, College of Fisheries, Washington Cooperative Fisheries Research Unit; 1977; Final Rep. 77-2. 44 p.

Southgate, B. A. Water pollution research, 1959: The report of the Water Pollution Research Board. London, Great Britain: Department of Scientific and Industrial Research: Her Majesty's Stationery Office. 1960. 331 p.

Sternberg, R. W.; Johnson, J. L. The birth and death of estuaries. Pacific Search. 12(4): 14-15; 1978.

Sumich, J. L. An introduction to the biology of marine life. Dubuque, IO: Wm. C. Brown Co. 1976. 348 p.

Sverdrup, H. U.; Johnson, M. W.; Fleming R. H. The oceans, their physics, chemistry, and general biology. Englewood Cliffs, NJ: Prentice-Hall, Inc.; 1942. 1087 p.

Swan, J. G. The northwest coast – or, three years' residence in Washington territory. First Pub.; Harper and Brothers, 1857. Wash. Paperback ed. Seattle, WA: University of Washington Press, 1972, 435 p.

Thayer, G. W.; Phillips, R. C. Importance of eelgrass beds in Puget Sound. Paper No. 1271. Marine Fisheries Review. 39(11): 18-22; 1977.

Thom, R. M. Primary productivity and organic carbon input to Grays Harbor estuary, Washington. Seattle, WA: U.S. Army Corps of Engineers, Seattle District, Environmental Resources Section; 1981. 70 p.

Thut, R. N.; Haydu, E. P. Effects of forest chemicals on aquatic life. In: Krygier, J. T.; Hall, J. D., eds. Forest land uses and stream environment: proceedings of a symposium; 1970 October 19-21; Corvallis, OR: Oregon State University; 1971: 159-171.

Toews, D. A. A.; Brownlee, M. J. A handbook for fish habitat protection on forest lands in British Columbia. Vancouver, B.C.: Department of Fisheries and Oceans; 1981. 173 p.

U.S. Army Corps of Engineers. Maintenance dredging and the environment of Grays Harbor, Washington. Seattle, WA: U.S. Army Corps of Engineers; 1976. 125 p.

U.S. Department of the Interior, Fish and Wildlife Service. Concept plan for waterfowl wintering habitat preservation – Washington and Oregon coasts, priority categories 14 and 15. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service. 1979. 174 p.

U.S. Environmental Protection Agency. Logging roads and protection of water quality. Seattle, WA: U.S. Environmental Protection Agency, Region X, Water Division. EPA 910/9-75-007. 1975. 312 p.

U.S. Geological Survey. Water resources data for Washington. Vol. 1: Western Washington. U.S. Geological Survey Water Data Rep. WA-79-1. 1979. 433 p.

Warren, C. E.; Doudoroff, P. Biology and water pollution control. Philadelphia, PA: W. B. Saunders Co.; 1971.

Welander, A. D. Notes on the dissemination of shad, (*Alosa sapidissima* Wilson), along the Pacific Coast of North America. Copeia. 4: 221-223; 1940.

Williams, R. W.; Laramie, R. M.; Ames, J. J. A catalog of Washington streams and salmon utilization. Vol. 1: Puget Sound region. Olympia, WA: Washington Department of Fisheries; 1975.

Woodcock, A. R. Annotated list of the birds of Oregon. Bull. 68. Corvallis, OR: Oregon Agricultural Experiment Station. 1902. 117 p.

Woodward, D. F. Assessing the hazard of picloram to cutthroat trout. J. Range Management. 32(3): 230-232; 1979.

Woodward, D. F.; Mayer, F. L., Jr. Toxicity of three herbicides (butyl, isooctyl, and propylene glycol butyl ether esters of 2,4-D) to cutthroat trout and lake trout. Tech. Pap. 97. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service; 1978. 6 p.

Zegers, P. The effects of log raft grounding on the benthic invertebrates of the Coos Estuary. Roseburg, OR: Oregon Department of Environmental Quality, Southwest Region; 1978. 45 p.

6

Edges

Wayne Logan
E. Reade Brown
Dean Longrie
Gene Herb
Robert A. Corthell

Table of Contents

Introduction

Edge occurs wherever two different environmental conditions meet. The amount of edge in a particular area can be used as a general indication of the diversity of wildlife habitats in that area. Edges provide some or all of the requirements for a wide variety of wildlife species. As a rule, greater habitat diversity means greater habitat richness and thus greater wildlife species richness (fig. 1).

Leopold (1933, pg. 131) was the first to state that "game (wildlife) is a phenomenon of edges." Wildlife "occurs where the types of food and cover which it needs come together, i.e., where their edges meet . . . We do not understand the reason for all of these edge-effects, but in those cases where we can guess the reason, it usually harks back either to the desirability of *simultaneous access* to more than one environmental type, or the *greater richness* of border vegetation, or both."

Intensive forest management practices in western Oregon and Washington forests have a substantial influence on the quantity and characteristics of edge habitat. Management of edges offers many opportunities to maintain or enhance wildlife populations within the forest environment.

Research on edges in forests west of the Cascade Range in Oregon and Washington has been limited. A comprehensive discussion of the ecological importance of edges, however, has been presented by Thomas et al. (1979) for the Blue Mountains area of Oregon and Washington. These relationships, broadly applicable to most forested ecosystems, will be used as the basis for much of the information presented in this chapter.

Figure 1.—Natural edges usually include several layers of vegetation.

Edges

An edge (fig. 2) is the place where plant communities meet or where successional stages or vegetative stand conditions within plant communities come together. The area influenced by the transition between communities or stand conditions is called an ecotone (fig. 3). Edges and their ecotones are usually richer in number of species of wildlife (Strelke and Dickson 1980) than the adjoining plant communities or stand conditions. As a result, they are an important consideration in wildlife management.

Figure 2.—An edge is the place where plant communities or successional stages (or stand conditions) within a plant community come together.

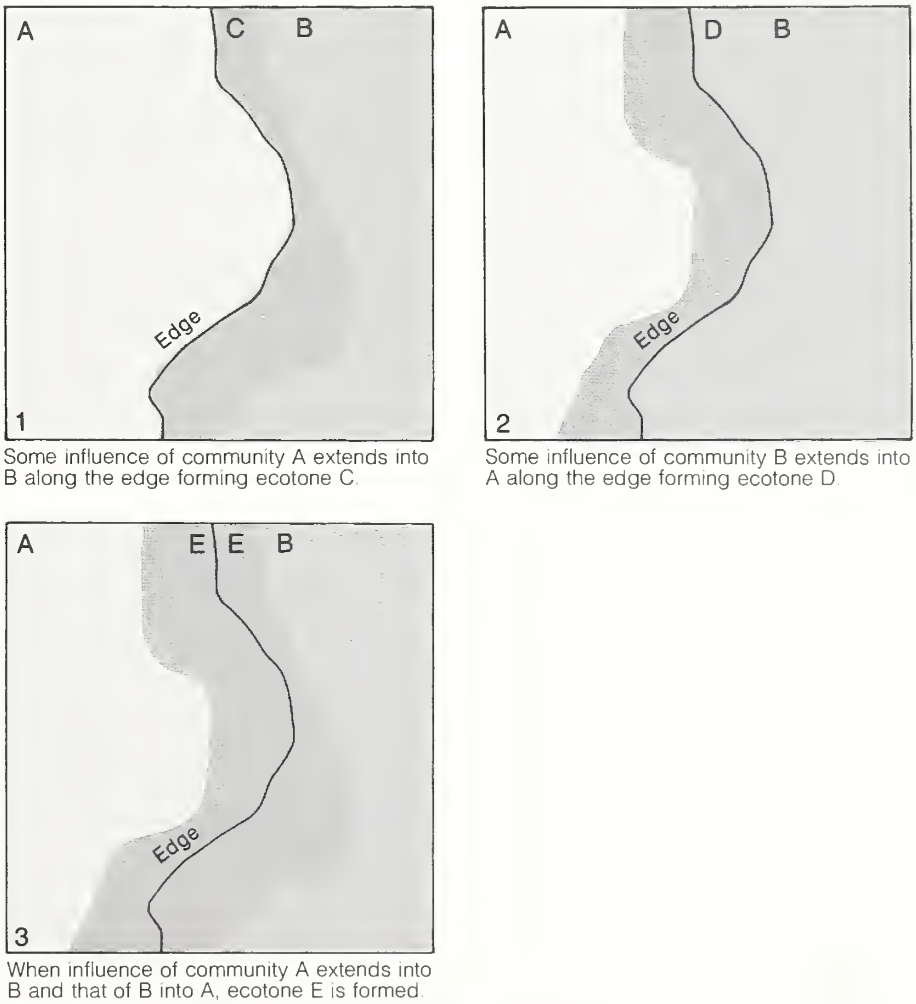
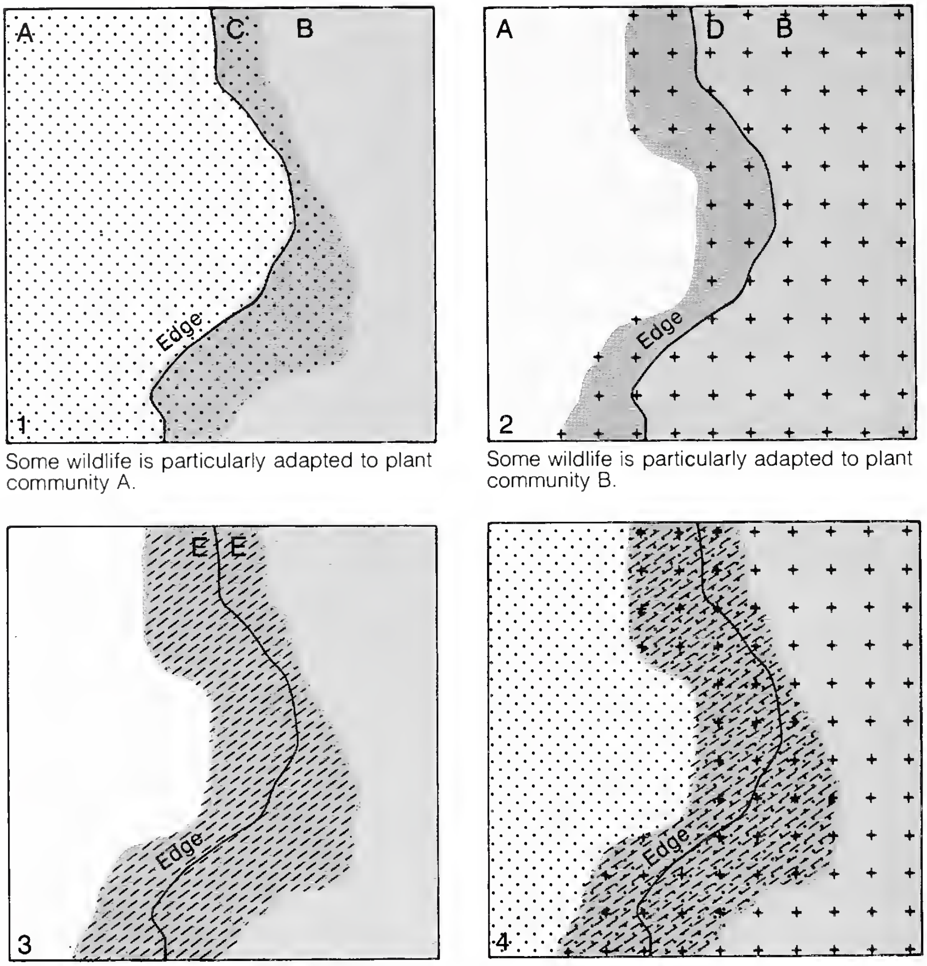


Figure 3.—Ecotones are formed along edges and may be created in several ways (from Thomas et al. 1979, p. 49).

"Habitat richness" is a term used to express the diversity of a habitat in species of plants or animals; the more species associated with the habitat, the richer it is. Edges are rich because of the additive effect on the fauna when two plant communities or stand conditions come together. Edges provide access to at least two plant communities or stand conditions for those species that are associated with more than one vegetative type. In the ecotone species common to either of the major plant communities may be found as well as other species that may be products of the ecotone itself (fig. 4). In another sense, wildlife richness reflects the plant and habitat diversity found in the ecotone (Thomas et al. 1979)

Types of Edges

Edges can be divided into two types, inherent and induced. Inherent edges result from geomorphic factors and tend to be stable features of the landscape. Induced edges normally result from disturbance factors and tend to be relatively short-lived.



1: Some wildlife is particularly adapted to plant community A.

2: Some wildlife is particularly adapted to plant community B.

3: Some wildlife is particularly adapted to ecotone E.

4: The total wildlife use in the ecotone indicates the habitat and species richness associated with edges.

Figure 4.—Species richness associated with edges reflects an additive effect (adapted from Thomas et al. 1979, p. 51).

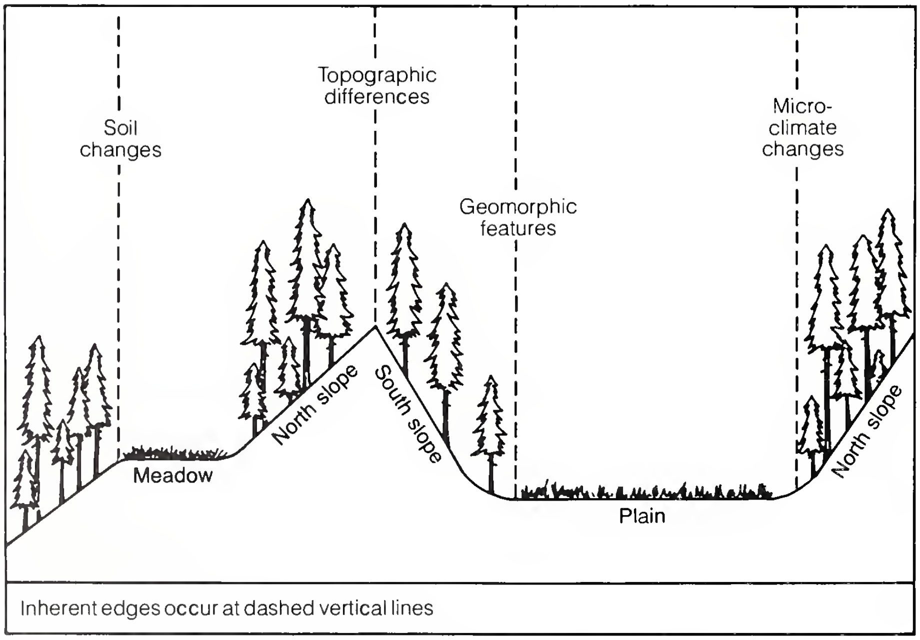


Figure 5.—Inherent edges are created when plant communities meet. The different communities result from soil changes, topographic differences, microclimate changes, or geomorphic features.

Inherent Edge

Edge that results from the meeting of two plant communities is an inherent edge (fig. 5). The plant communities that create these edges result from the many factors that influence a site such as soils, topography, and microclimate (Daubenmire 1976). These communities normally persist over long periods although gradual modifications in soils or microclimates may result in some shifting of plant communities. Broadened ecotones or mosaic patterns may emerge. Occasionally, an inherent edge may be created abruptly, such as in a massive landslide or with severe erosion or deposition.

High contrast inherent edges occur at locations where two vastly different geomorphic features meet such as the interface in a riparian zone between the water and a plant community at the water's edge or where a plant community meets a cliff face. Intermediate contrast edges are found where similar geomorphic features exist but these features are affected by topography or microclimate such as north and south facing slopes or where frost pockets create distinctly different plant communities. Low contrast edges develop where geomorphic features such as different soil types result in different plant communities. High contrast edges usually are abrupt whereas low contrast edges are more subtle.

Plant communites that form an inherent edge may be modified by management activities or other short term phenomena such as fire, but the edge will soon reappear as the vegetation returns to its previous condition. The underlying factors that caused the edge or difference in plant communities usually do not change.

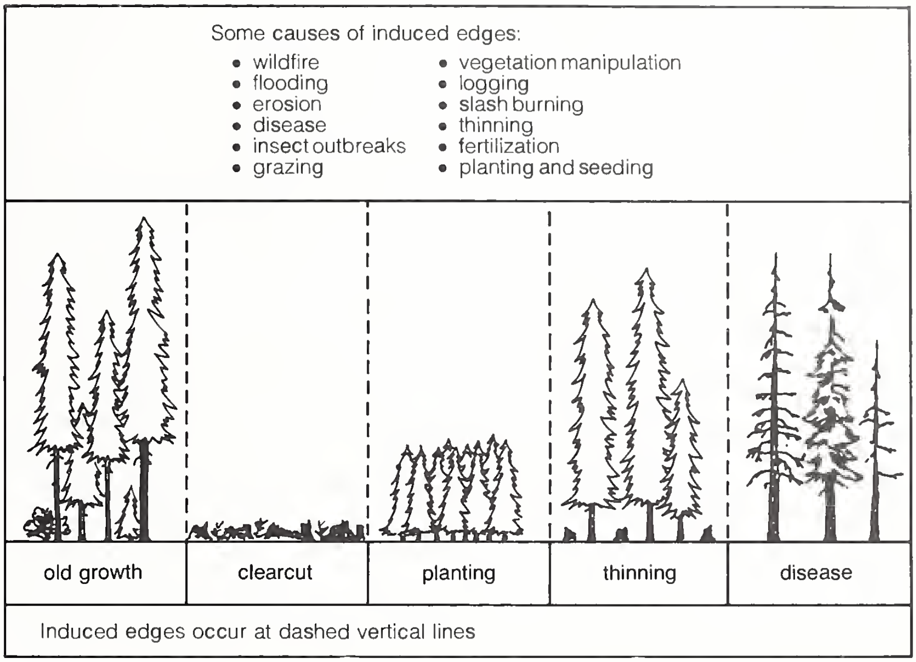


Figure 6.—Induced edges are created by short-term natural phenomena or management practices that change successional stages or stand conditions within a community (adapted from Thomas et al. 1979, p. 50).

Induced Edge

An induced edge results when the structure of vegetation within a plant community is altered, usually as the result of disturbance factors. These disturbance factors may be natural such as wildfire, severe wind, disease and insect outbreaks, flooding, or erosion. They also result from forest management activities such as timber harvest, slash burning, planting and seeding, and thinning (fig. 6).

Induced edges also may have high contrast such as the edge between a clearcut and an old-growth forest stand or low contrast such as the edge between the shrub stand condition and the open sapling-pole stand condition. Induced edges, in comparison to inherent edges, are relatively short-lived in the moist mild climate of western Oregon and Washington. Although induced edges may persist for many years, they are constantly changing as the vegetation changes from one stand condition to another and usually are not permanent features of the landscape.

Characteristics of Edges

Edges and their associated ecotone may be characterized by their length, width, height, contrast, and dispersion. Combined, these factors determine the amount of edge in an area, the contribution of edge to species richness (fig. 7), and ultimately its overall influence on wildlife populations.

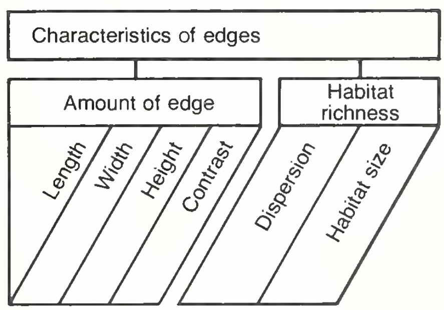


Figure 7.—Edge characteristics influence the amount of habitat and species richness (adapted from Thomas et al. 1979, p. 52).

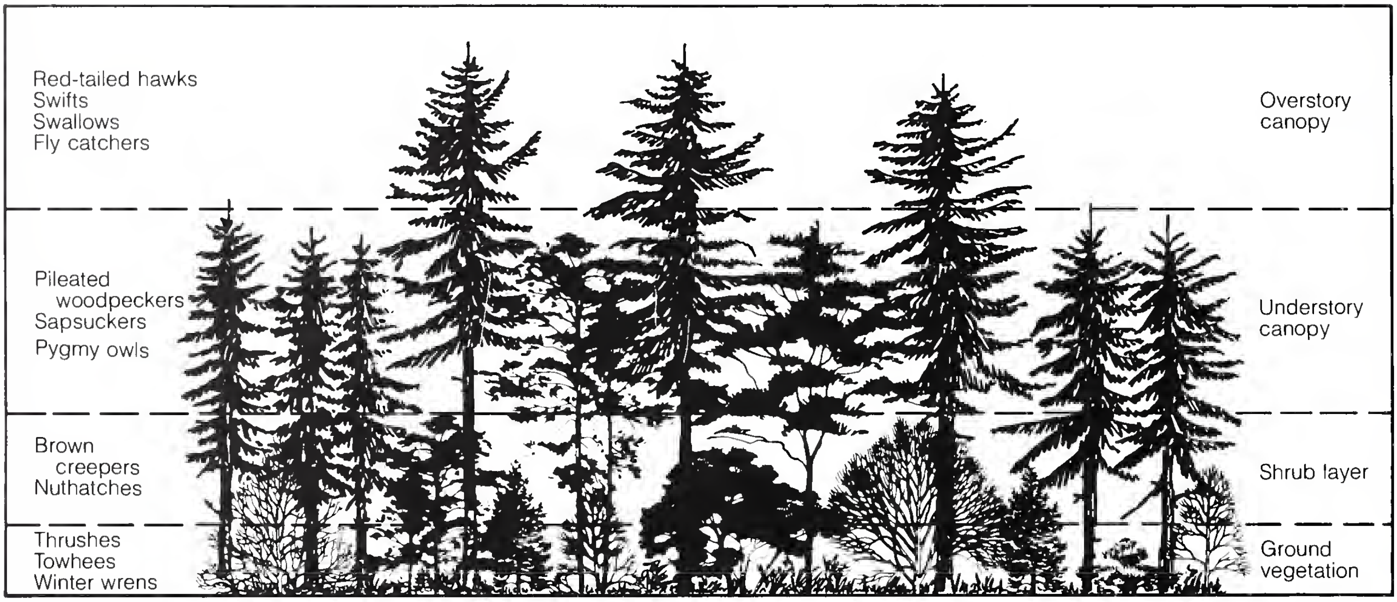


Figure 8.—Four layers of a mature forest, with the birds that typically inhabit each.

Edge length is the linear distance around the perimeter of a plant community or stand condition within that community. Edge width is more difficult to determine, but generally is wider than the recognizable changes in vegetation on either side of the edge. These width and length measurements can be used to determine the area of the ecotone. An abrupt narrow edge, common with induced edges, yields less ecotone than the wider, inherent edges. Edge height is the maximum height of vegetation in the plant community and determines the number of layers of foliage available for different wildlife users (fig. 8).

Figure 9.—Narrow abrupt edges limit the amount of edge habitat, but the high contrast between the two stand conditions making up the edge, increases species richness.

Contrast pertains to the types of plant communities or stand conditions that create the edge. An edge between the "grass-forb dry hillside" and the "mixed coniferous forest" communities will result in a greater contrast and more diverse wildlife habitats than would an edge between the "temperate coniferous forest" and the "high temperate coniferous forest" communities. Also an edge between an area in the "grass-forb" stand condition and an area in the "old growth" stand condition will provide greater contrast than would an edge between the "shrub" and the "open-sapling-pole" stand conditions (fig. 9).

Dispersion involves the arrangement of edges on an area which ranges from simple straight lines to complicated mosaics (fig. 10). Inherent edges more often tend toward mosaic patterns whereas induced edges, especially those resulting from clearcut timber harvesting in western Oregon and Washington, tend toward straight lines.

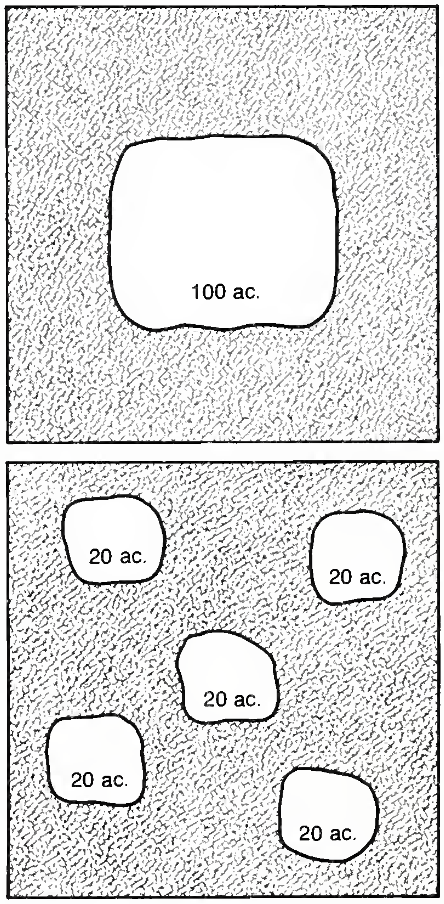


Figure 10.—Dispersion of edge.

Value for Wildlife

The richness of edge habitat for wildlife is determined particularly by the degree of contrast between the plant communities or stand conditions forming the edge and the dispersion of these edges on an area (fig. 11). The greater the contrast, the more likely the adjoining habitats will have different structures and thus support different wildlife species. Contrast tends to increase the species richness of the ecotone. The six stand conditions, illustrated in figure 12, can combine to form 15 different kinds of edge, each with a differing degree of contrast. Little contrast is produced by combining closely related stand conditions. Contrast can be dramatic, however, if an early successional stand condition is combined with mature timber or old-growth stand conditions. The degree of contrast may be determined by subtracting the smaller identifying number from the larger. The greater the difference, the greater the contrast.

Figure 11.—Irregular harvest units significantly increase the amount of edge habitat.

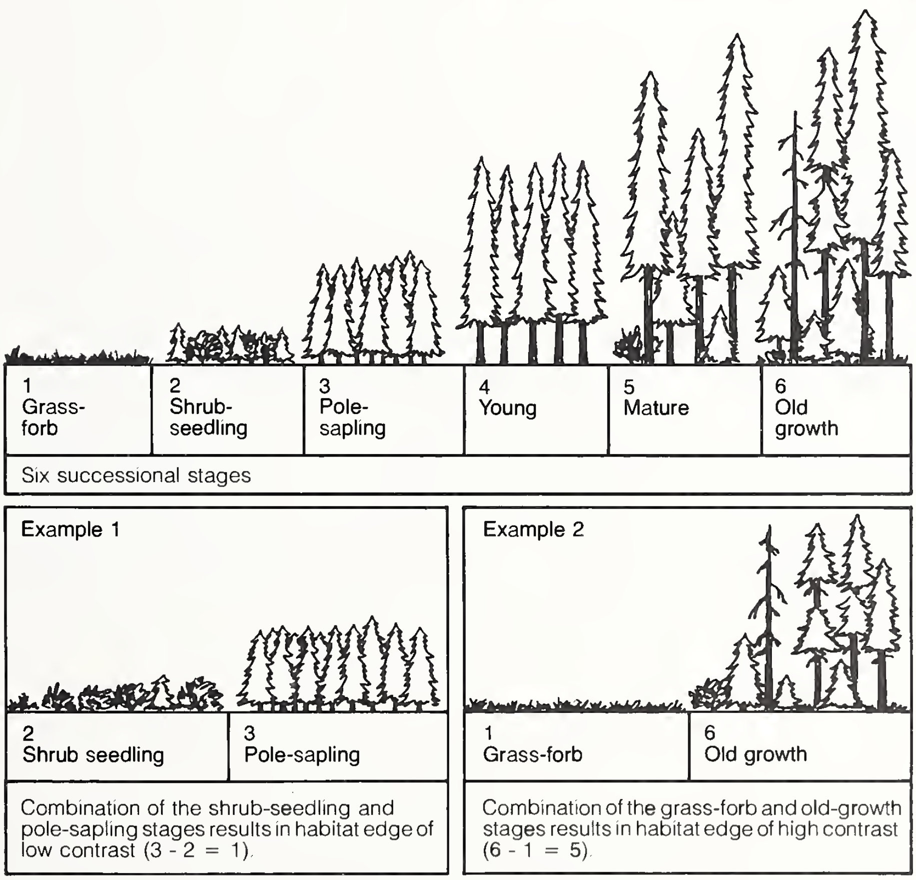


Figure 12.—Edges differ in their degree of contrast (from Thomas et al. 1979, p. 52).

Not only does the edge between two habitat types result in an overlapping of the wildlife species adapted to each of the habitat types, but certain species are attracted to the edge or ecotone between the types that are not normally found in either habitat type (Gates and Gysel 1978, Strelke and Dickson 1980). These combinations increase the species richness of the edge. Many bird species are especially attracted to edges because of the greater structural diversity of the vegetation making up the edge (Beedy 1981, Kessler 1979, Morgan and Gates 1982, Strelke and Dickson 1980). Big game animals also show an affinity for edges, probably because of the close association of cover and foraging areas (Hanley 1983, Willms 1971, Witmer 1981).

Diversity

Diversity has been defined by Boyce and Cost (1978) as "the meaningful differences in the elements of biological communities." Siderits and Radtke (1977) define it as "a variety of plant and wildlife communities within a given area." They further point out ". . . all components of the ecosystem; the plant, animal, fish, and bird life; along with soils and climate, comprise the factors to be evaluated in a sound land management program." In the forested areas of western Oregon and Washington, the diversity of habitats available to wildlife will be dependent to a large degree on the management of the forest resources.

Importance of Diversity

Maintenance of ecological diversity is thought to be directly related to stability and as such will help to insure the system against disaster (Jenkins 1976, Margalef 1969, Thomas et al. 1978). For many years management programs focused on a single species or product without regard to their impact on other resources. Now attention is turning toward truly integrated multiple-use management that encompasses many products and concerns such as wood fiber, water, wildlife, range and aesthetics (Harris and Marion 1982). Also, recent federal regulations and policies have required that diversity of wildlife and wildlife habitats be one of the goals of land use planning (Salwasser and Tappeiner 1981).

In western Oregon and Washington structurally complex natural forest stands are being rapidly replaced with more simplified even-age stands. In the intensively managed forest, young second-growth conifer stands will be the dominant feature. Clearcuts and old-growth forest, the two classes that offer the greatest wildlife habitat diversity, will make up only a small part of the landscape. For many wildlife species, within-stand diversity is lost when natural forest stands are removed. Creation of among-stand diversity resulting from timber harvesting units may partially compensate for these losses. If wildlife habitats are to be maintained or enhanced, scheduling decisions concerning the shape, size, location, and timing of clearcuts become critical. The size and shape of cutting units cannot be altered once they are created and the shape of one forest stand or opening affects the shapes of adjacent openings created by later cutting. Also, considerations of how long a stand will stay in a particular growth stage should be taken into account in management decisions (Marcot and Meretsky 1983, Mealy et al. 1982).

Diversity and Stand Size

Stand size and shape determine the dispersion of edges and are important in determining the richness of that habitat for wildlife. As the amount of edge in an area increases, habitat diversity increases but this is true only to a certain point. For example, a single habitat block of 50 acres can support a much greater variety of wildlife species than can 50 one-acre blocks because the differing habitat requirements of a much larger number of species can be met in the larger block. Even though it would appear there is a greater diversity of habitat with 50 small blocks than with one large block, there is a point where increasing diversity tends toward homogeneity. As Thomas et al. (1978) stated, "The point at which increasing diversity tends to become decreasing diversity is that point where the average size of the habitat blocks becomes smaller than the size required to maximize the number of species present." The number of species in an area is an indicator of habitat diversity (Cain and Castro 1959, Greig-Smith 1964). Number of species usually increases along with the size of the habitat block up to the point where increasing size results in decreasing diversity (Hopkins 1955, MacArthur and Wilson 1967, Preston 1960, Soule and Wilcox 1980).

Galli et al. (1976), working with bird species in New Jersey, found that the number of species increased significantly with increasing block sizes up to 60 acres. This rate of increase in number of species slowed significantly between the 60 acre block size and one of 110 acres, indicating larger block sizes would result in only limited increases in species. They attributed the increase in number of bird species as habitat block size increased to the following: (1) the addition of new species as their minimum habitat size requirements were met; (2) the inclusion of specific habitat components in sufficient quantity; and (3) the presence of specialized conditions in the interior of the habitat block.

As habitat block size increased, insectivorous or carnivorous bird species were attracted and accounted for the increase in the number of species. No further increase in species numbers occurred when a block size was reached where species adapted to edges started declining (Galli et al. 1976). MacClintock et al. (1977), however, found that small habitat blocks connected by corridors to larger blocks had a wildlife species composition similar to the larger block. Isolated small blocks had a much lower wildlife species composition. They attributed the difference to an interchange of species that occurred as the result of the connecting corridor.

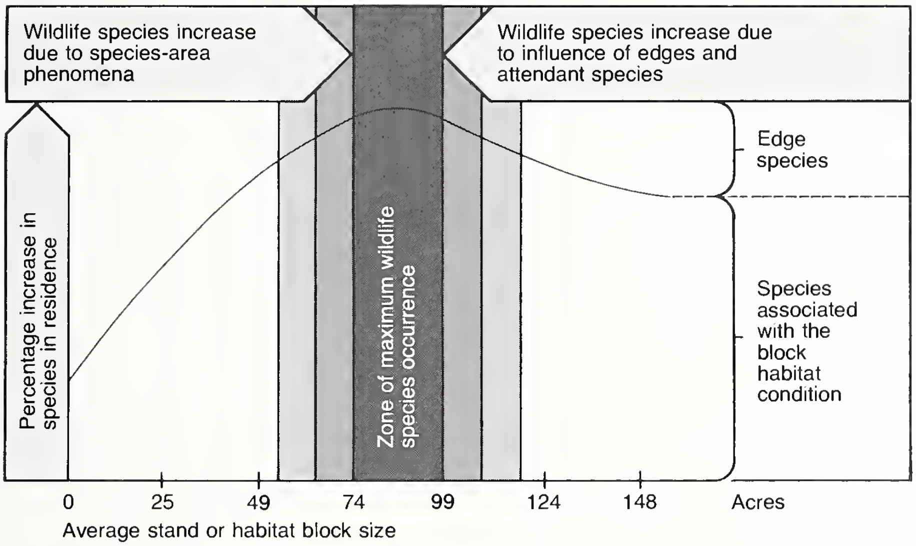


Figure 13.—Wildlife diversity is related to the average size of habitat blocks. The curve is generalized from data presented by Galli et al. (1976) for bird populations (adapted from Thomas et al. 1979, p. 53).

Figure 14.—Large blocks of older forest provide habitat for wide-ranging species.

Since no similar studies have been conducted in the northwest, Thomas et al. (1979) using Galli's et al. (1976) data developed a "best estimate" that maximum species richness, at least for birds, would be achieved with a stand size of about 84 acres (fig. 13). Bird species richness was assumed to be a reasonable indicator of the relationship of all vertebrate wildlife to stand size. With an "average" stand size of about 84 acres wildlife species richness attributable strictly to stand size should approach maximum. Note that the word *average* is used in relation to stand size indicating that stands both larger and smaller than 84 acres are included.

Some species, particularly those not associated with edge habitats may require large habitat blocks (fig. 14). Bull (1975) found that the pileated woodpecker in northeastern Oregon used at least 300 acres of older forest during the nesting season. Recent work by Forsman (1980, 1981) in western Oregon with the northern spotted owl, one of the top avian predators in old-growth forests, indicates that this species needs a very large territory (see chapter 12). Radiotagged birds foraged over areas ranging in size from 1,350 acres to over 8,000 acres, depending on the amount of old-growth forest remaining. Although extensive stands may not have maximum diversity, they do provide sufficient habitat for several unique species that contribute to regional diversity (Forman et al. 1976). The spotted owl, for example, requires extremely large areas of similar habitat and will suffer if smaller areas are substituted. Other species, such as Roosevelt elk, may simply require solitude or protection from the intrusions of man. In such cases, regulation of man's activities may suffice in lieu of preservation of large areas of pristine habitat. This must be determined on a species by species basis.

Edge as a Measure of Habitat Diversity

If habitat diversity is a goal in management planning, there must be a means of measuring and accounting for it in developing these plans. Edges, both inherent and induced, are a direct reflection of the total diversity of an area (Thomas et al. 1979).

As Thomas et al. (1979) points out, standard diversity indices require information about numbers of plant and animal species along with their frequency of occurrence. Such approaches are usually not possible because of a lack of information or because they are too expensive for most land use planning. A feasible alternative, however, is to use edge as an indicator, or index of diversity. Thomas et al. (1979) lists three uses for such an index in forest land management: "(1) to investigate trends in habitat diversity, (2) to evaluate management alternatives for their immediate and long-term effects on diversity, and (3) to evaluate the effect of the shape of timber harvest areas on diversity."

A Diversity Index

An index was developed by Patton (1975) that evaluated the edge of any habitat area. This system compared the irregularity of a habitat area with that of a circle to determine a diversity index (DI), (fig. 15). In the complex vegetative conditions found in western Oregon and Washington several types of edges often occur adjacent to or within a habitat management area. Thomas et al. (1979) modified Patton's diversity index to include two different types of edge, inherent and induced (fig. 16), which makes it more applicable in land-use planning and land management. He points out, "Inherent edges are site related and are created when plant communities meet. Such edges may be considered as the degree of diversity given to the area. Induced edges occur when successional stages or conditions within plant communities come together. Induced edges can be produced when and where desired by the forest land manager; however, they are certain to result from any activity that alters vegetative structure."

The modifications in Patton's (1975) diversity index formula proposed by Thomas et al. (1979) are shown in appendix 17 along with a procedure that can be used in calculating the total diversity index for a management area.

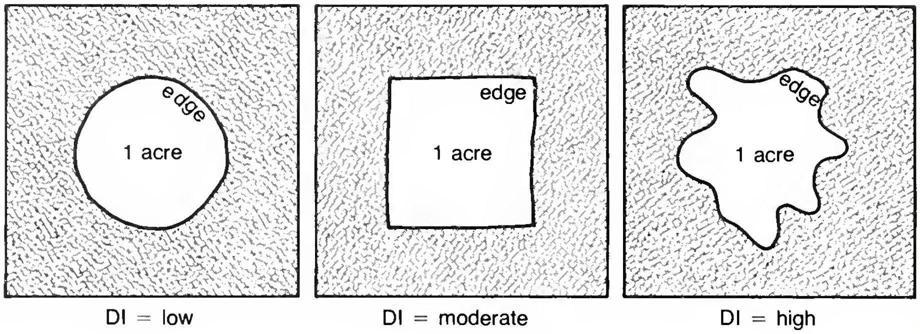


Figure 15.—The more irregular the edge the greater the diversity index (DI).

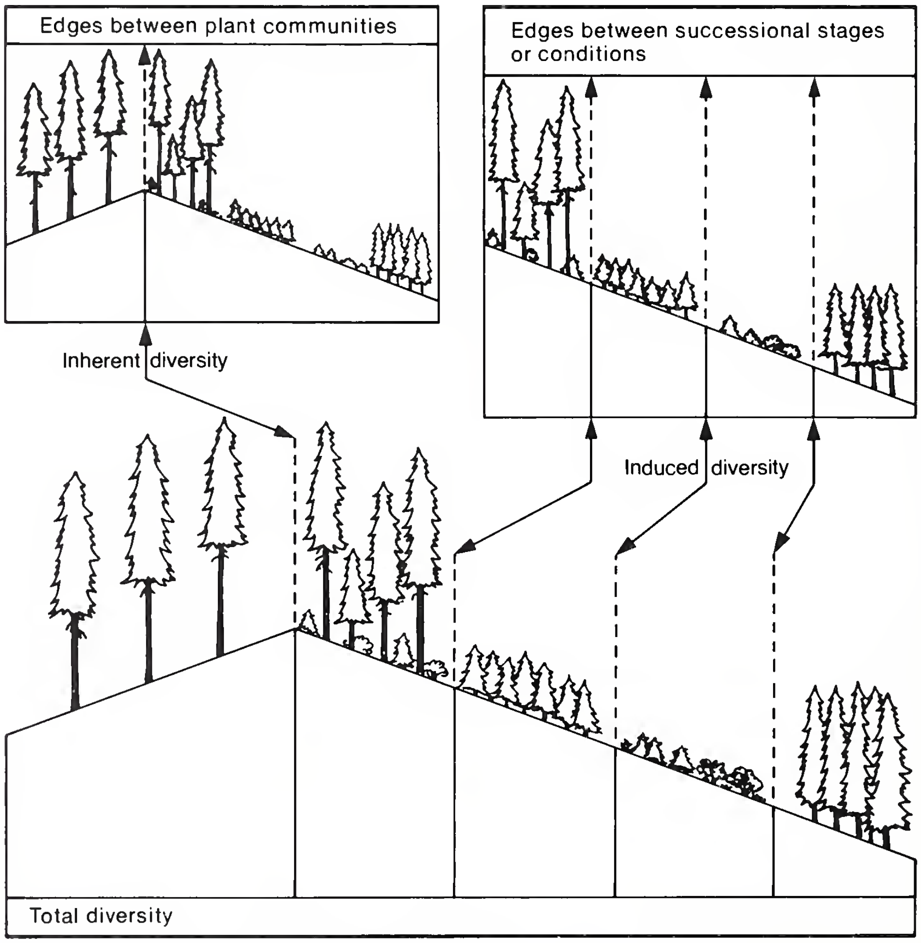


Figure 16.—The amount and arrangement of edge is an expression of habitat diversity (from Thomas et al. 1979, p. 54).

Management Considerations

Wildlife habitats within the managed forests of western Oregon and Washington are constantly changing, either through natural succession or some man-caused alteration. The degree to which these changes are beneficial to desired wildlife species will depend to a large degree on the planning and execution of timber management practices. Primary objectives should include one of maintaining habitat diversity while insuring that future options are not lost through present management decisions (Siderits and Radtke 1977).

Although maintaining habitat diversity is a worthwhile goal for land-use planners, it must be used with caution. The degree of habitat diversity can be "good" or "bad" only in relation to management goals and objectives. A program for maximum diversity would certainly not be appropriate if a management objective was to maintain habitat for spotted owls. Gill et al. (1976) point out that a mix of management for both species richness and featured species management is usually feasible. Such a program should preclude the loss of any species while insuring desired yields of featured species—usually game or threatened or endangered species.

As Thomas et al. (1979) said: "Each forest area has a unique set of possibilities for diversity. One area may have a high degree of diversity as a result of its inherent mixture of communities. Such an area may have low priority for management to increase diversity. Conversely, an area may have only one or a few communities all in the same successional stage or condition and may be a good candidate for improvement in diversity if that is in keeping with management objectives."

In the intensively managed forests of western Oregon and Washington, maintenance of structural diversity is also important. These managed stands are more simplified than structurally diverse natural stands, although among-stand heterogeneity or structural diversity may be increased. From a wildlife diversity standpoint, it is desirable to maintain a mix of natural stands containing within-stand structural diversity along with the more simplified planted stands, so as to create both within-stand and among-stand diversity at various scales (Harris and Marion 1982).

Figure 17.—Induced edges will provide better wildlife habitat if they are designed to more closely duplicate wider natural edges.

The wildlife management objectives for species richness or featured species will determine the quality and quantity of edge habitat to be maintained (fig. 17). The following habitat relationship considerations and options may be useful to the land manager in developing plans for maintaining or enhancing edge habitats.

Inherent Edges

Considerations

Inherent edges formed around natural meadows, ponds, marshes and ridgetops are especially high in habitat richness. Natural edges are sensitive nesting and foraging areas. These types of edges are particularly limited within the contiguous forests west of the Cascade Range. Therefore, vegetation modifications and/or human disturbances should be kept to a minimum.

Options

- Best management for these natural edges is no disturbance;
- Roads and trails that encourage human disturbance should be kept away from edge areas;
- If disturbance is unavoidable, impact only a small portion of the edge.

Induced Edges

Considerations

Induced edges in managed forests are caused primarily by timber harvest. Harvest units need to be planned in time and space to maintain a "sustained edge effect" within a given area and a specified level of habitat diversity throughout the timber rotation.

Options

- Design harvest units with irregular boundaries to increase length of edge habitat;
- Leave natural, wide edges undisturbed and make narrow abrupt edges wider by selectively leaving a variety of plants along the induced edge. Wide edges can provide greater amounts of ecotone for increased wildlife use;
- Place harvest boundaries beyond the tallest vegetation of the outer ecotone to maintain additional layers of foliage. Height of vegetation determines the number of layers of foliage. Each layer of foliage provides additional habitat for wildlife;

- Separate harvest units to increase dispersion. Dispersion is the overall pattern of vegetation changes within a habitat area. A mosaic pattern of units creates more edge and greater mixing of that edge in the habitat area;
- Plan harvest units to create the greatest age class contrast. The higher the contrast the greater the species richness;
- Leave large and small stands of both managed and unmanaged forest to increase diversity. Small forest stands support a high diversity of species and maintain habitat stepping stones between large forest stands. Large forest stands have the habitat required by wider ranging species.

In conclusion Thomas et al. (1979) states: "Diversity is meaningful only in the context of clearly stated forest management objectives. If diversity is a goal of land management, it can be accomplished only if the manager is willing to measure changes in diversity. Without a concise statement of goals and adequate measurement of diversity, forest managers cannot be held accountable."

References Cited

Beedy, E. C. Bird communities and forest structure in the Sierra Nevada of California. Condor. 83(2): 97-105; 1981.

Boyce, S. G.; Cost, N. D. Forest diversity-new concepts and applications. Res. Pap. SE-194. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1978. 36 p.

Bull, E. L. Habitat utilization of the pileated woodpecker, Blue Mountains, Oregon. Corvallis, OR: Oregon State University; 1975. 58 p. Thesis.

Cain, S. A.; de Oliveira Castro, G. M. Manual of vegetation analysis. New York: Harper and Brothers; 1959. 325 p.

Daubenmire, R. The use of vegetation in assessing the productivitiy of forest lands. Bot. Rev. 42(2): 115-143; 1976.

Forman, R. T. T.; Galli, A. E.; Leck, C. F. Forest size and avian diversity in New Jersey woodlots with some land use implications. Oecologia. 26: 1-8. 1976.

Forsman, E. D. Habitat utilization by spotted owls in west-central Cascades of Oregon. Corvallis, OR: Oregon State University: 1980. 95 p. Dissertation.

Forsman, E. D. Habitat utilization by spotted owls on the Eugene District of the Bureau of Land Management. Tech. Rep. Portland, OR: U.S. Department of the Interior, Bureau of Land Mangement; 1981. 63 p.

Galli, A. E.; Leck, C. F.; Forman, R. T. T. Avian distribution patterns in forest islands of different sizes in central New Jersey. Auk. 93(2): 356-364; 1976.

Gates, E. F.; Gysel, L. W. Avian nest dispersion and fledging success in field forest ecotones. Ecology. 59(5): 871-883; 1978.

Gill, J. D.; Radtke, R. E.; Thomas, J. W. Forest wildlife habitat management: Ecological and management systems. In: The scientific base for silviculture and mangement decisions in the National Forest System. Washington, DC: U.S. Department of Agriculutre, Forest Service; 1976: 52-58.

Greig-Smith, P. Quantitative plant ecology. 2d ed. London: Butterworths; 1964, 256 p.

Hanley, T. A. Black-tailed deer, elk, and forest edge in a western Cascades watershed. J. Wildl. Manage. 47(1): 237-242; 1983.

Harris, L. D.; Marion, W. R. Forest stand scheduling for wildlife in the multiple use forest. In: Increasing forest productivitiy: Proceedings of the 1981 convention of the Society of American Foresters. Washington, DC: The Society of American Foresters; 1982; 209-214.

Hopkins, B. The species-area relations of plant communities. J. Ecol. 43(2): 409-426; 1955.

Jenkins, R. Maintenance of natural diversity: Approach and recommendations. In: 41st North Am. Wild. and Nat. Resour. Conf. Trans.; Washington, DC: Wildlife Management Institute; 1976: 441-451.

Kessler, W. B. Bird population responses to clearcutting in the Tongass National Forest of Southeast Alaska. Rep. No. 71. Ketchikan, AK: U.S. Department of Agriculture, Forest Service, Alaska Region, Tongass National Forest; 1979. 22 p.

Leopold, A. Game mangement. New York: Charles Scribner Sons; 1933. 481 p.

MacArthur, R. H.; Wilson, E. O. The theory of island biogeography. Princeton, NJ: Princeton University Press; 1967. 203 p.

MacClintock, L.; Whitcomb, R. F.; Whitcomb, B. L. II. Evidence for the value of corridors and minimization of isolation in preservation of biotic diversity. American Birds 31: 6-16; 1977.

Marcot, B. G.; Meretsky, V. J. Shaping stands to enhance habitat diversity. J. of For. 81(8): 526-528; 1983.

Margalef, R. Diversity and stability: A practical proposal and a model of interdependance. In: Diversity and stability in ecological systems. Upton, NY: Brookhaven National Laboratory, Brookhaven Symp. Biol. 22: 25-37; 1969.

Mealey, S. P.; Lipscomb, J. F.; Johnson, K. N. Solving the habitat dispersion problem in forest planning. 47th North Am. Wild. and Nat. Resour. Conf. Trans.; Washington, DC: Wildlife Management Institute; 1982: 142-153.

Morgan, K. A.; Gates, J. E. Bird population patterns in forest edge and strip vegetation at Remington Farms, Maryland. J. Wild. Manage. 46(4): 933-944; 1982.

Patton, D. R. A diversity index for quantifying habitat "edge". Wild. Soc. Bull. 3(4): 171-173; 1975.

Preston, F. W. Time and space and the variation of species. Ecology. 41(4): 611-627; 1960.

Salwasser, H.; Tappeiner II, J. C. An ecosystem approach to integrated timber and wildlife habitat management. 46th North Am. Wild. and Nat. Resour. Conf. Trans.; Washington, DC: Wildlife Management Institute; 1981: 473-487.

Siderits, K.; Radtke, R. E. Enhancing forest wildlife habitat through diversity. 42nd North Am. Wild. and Nat. Resour. Conf. Trans.; Washington, DC: Wildlife Mangement Institute; 1977: 425-434.

Soule, M. E.; Wilcox, B. A. Conservation biology: an evolutionary-ecological perspective. Sunderland, MA: Sinauer Associates; 1980. 395 p.

Strelke, W. K.; Dickson, J. G. Effect of forest clearcut edge on breeding birds in East Texas. J. Wild. Manage. 44(3): 559-567; 1980.

Thomas, J. W.; Maser, C.; Rodiek, J. E. Edges – their interspersion, resulting diversity, and its measurement. In: Degraaf, R. M., Tech. Coord. Proceedings of the workshop on non-game bird habitat management in the coniferous forests of the western United States. 1977 February 7-9; Portland, OR. General Tech. Rep. PNW-64. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1978: 91-100.

Thomas, J. W.; Maser, C.; Rodiek, J. E. Edges. In: Thomas, J. W., Tech. Ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agriculture Handbook 553. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979: 48-59.

Willms, W. D. The influence of forest edge, elevation, aspect, site index, and roads on deer use of logged and mature forest, northern Vancouver Island. Vancouver, BC: University of British Columbia; 1971. 184 p. Thesis.

Witmer, G. W. Roosevelt elk habitat use in the Oregon Coast Range. Corvallis, OR: Oregon State University; 1981. 104 p. Dissertation.

7

Snags (Wildlife Trees)

William A. Neitro
Virgil W. Binkley
Steven P. Cline
R. William Mannan
Bruce G. Marcot
Douglas Taylor
Frank F. Wagner

Table of Contents

Introduction

Snags are an important structural component in forest communities. In forests of western Oregon and Washington, snags are used by nearly 100 species of wildlife of which at least 53 species (39 birds and 14 mammals) are cavity-dependent. Wildlife species that use cavities in partially live or dead trees for various life functions are referred to as cavity users or nesters, and include representatives from all classes of terrestrial animals. The dependency of these species on dead trees ranges from absolute to incidental, but for some species the presence of dead trees can spell the difference between local extinction and the perpetuation of existing populations. In forests, cavity-nesting birds may account for 30-45 percent of the total bird population (Jackman 1974a, Raphael and White 1984, Scott et al. 1980). Woodpeckers are dependent on snags and other dead wood for nesting, roosting, foraging, and other functions. Woodpecker nest cavities when abandoned are used by other animals (secondary cavity users) for nest sites. Some researchers believe that the use of cavities has allowed birds to become polygamous, nest earlier, have larger clutches, and fledge more young per nesting effort than noncavity-nesting birds (Nice 1957, Steinhart 1981).

The absence of suitable snags can be the major limiting factor for some snag-dependent wildlife populations (Haapanen 1965, Balda 1975). The abundance and diversity of hole-nesting birds are directly related to the dead and dying wood characteristics and general vegetation features of a forest. Morrison and Morrison (1983), in analyzing 30 years of Audubon Society Christmas bird count data, found that populations of three species -- common (northern) flicker, hairy woodpecker, and downy woodpecker -- show a downward trend in the Pacific Northwest. They speculate that this may be the result of intensive forest management practices.

Some species decrease whereas others increase with changes in vegetation structure (Manuwal and Zarnowitz 1981). Hagar (1960) reported that logging could make an area as suitable as an unmanaged forest for some species of woodpeckers. Northern flickers and hairy woodpeckers actually increased after logging when snags were retained. From the 1940s through the early 1960s the Oregon Conservation Act of 1942 (repealed) inadvertently provided snags in managed young forests. This act required the replanting of harvested sites or the retention of seed trees. These old seed trees, many now dead or dying, often became snags (fig. 1).

Figure 1.—Retained seed trees often become future large snags.

Today, silvicultural practices are often aimed at producing even-aged forest stands with low vertical structural diversity (Wiens 1978). These single canopy stands usually have been "sanitized" by removal of snags, defective trees and salvageable cull logs (chip and peeler logs). As the practice of even-aged forest management extends to larger areas in Oregon and Washington, populations of cavity-nesting species are likely to be reduced (Manuwal and Zarnowitz 1981).

For example, Morrison and Meslow (1983) reported that breeding cavity-nesting species were rare on recent clearcuts (10 years old or less) studied in the Coast Ranges of Oregon. In older second growth managed forests with few trees suitable for cavity construction, intraspecific and interspecific competition among cavity-nesting species may be high (Jackson 1979, Manuwal and Zarnowitz 1981).

The basic conflict between hole nesters and commercial timber management relates to the systematic and maximum utilization of forest wood fiber and to the concern for fire control and safe working conditions (Franklin et al. 1981, Haapanen 1965, Jackman 1974a, Meslow 1978). Over the past two decades new technology and declining wood supplies have increased the utilization of lower quality forest trees and logging residues. Snags, cull trees and residue logs are often salvaged for wood chip products and firewood. In the future, logging debris may be used to generate electricity, thus posing an added threat to retention of snags for wildlife.

The objectives of this chapter are fourfold: 1) to describe the characteristics and dynamics of snag habitat in unmanaged and intensively managed Douglas-fir forests; 2) to describe the wildlife that use snags, and the role and importance of snag-dependent wildlife; 3) to estimate the snag requirements of hole-nesting birds in managed forests; and 4) to describe some techniques for snag management in managed forests.

Importance and Role of Snags in the Forest Ecosystem

Dead and partially dead trees are important to many species of wildlife and function in a variety of ways (table 1). Recognition of the importance of snags to wildlife dates back over 60 years when Grinnell and Storer (1924) recommended leaving dead trees for breeding, shelter, and food needs of wildlife. More recently, the importance of snags to wildlife has been investigated and described by many authorities (Bull 1978, Bull and Meslow 1977, Cline 1977, Mannan et al. 1980). Thomas et al. (1979) described a direct correlation between the abundance of snags and the abundance of cavity nesters. Mannan et al. (1980) confirmed this correlation with hole-nesting birds in western Oregon.

Definition of Snags as Wildlife Trees

For a snag to be suitable as a cavity site for wildlife, its diameter must be large enough to accommodate cavity users. Most hole nesting birds have been shown to prefer snags with a diameter greater than 15 inches and to select specific stages of snag decomposition for feeding and nesting (Gale (1973, Mannan et al. 1980, Raphael 1980). Conner (1978) further described the visual indicators of a tree having potential for nest sites to include the presence of fungal conks, rotting dead branch stubs, old wounds, scars and existing woodpecker cavities. In this chapter snags will be defined as any dead, partially-dead or defective (cull) tree at least 10 inches in diameter at breast height (d.b.h.) and at least 6 feet tall. Smaller diameters may be useful to some species for feeding. The term "green" wildlife tree is used to identify trees that could be designated future snag habitat.

Other definitions of snags are generally concerned with forestry practices, potential safety, and fire prevention.

Table 1 —Some uses of snags by selected wildlife species

USE	Pileated woodpecker	Red-breasted sapsucker	Acorn woodpecker	Turkey vulture	Owls and raptors	Osprey	Bald eagle	Flycatchers	Brown creeper	Bats	Raccoon and black bear	Small mammals	SOURCE
Cavity nest sites	X	X	X		X							X	Jackman 1974a Bull 1978 Gale 1973
Nesting Platforms						X	X						Zarn 1974 Miller & Miller 1980
Feeding substrate	X	X	X						X				White & Raphael 1975 Raphael & White 1976 Evans & Conner 1979 Bull 1978
Plucking posts					X								Miller & Miller 1980
Singing or drumming (communication)	X	X	X										Jackman 1974b Bull 1975 Rushmore 1973
Food cache or granary			X									X	Swearingen 1977 Balgooyen 1976 Scott 1978
Location of courtship	X	X	X										Kilham 1979 Jackman 1974b Jackson 1976
Overwintering sites	X		X		X					X	X	X	Bent 1964 McClelland 1979
Roosting	X	X	X	X	X	X	X			X			Chapter 13 Maser et al. 1981b Scott 1978
Lookout posts				X	X	X	X	X					Miller & Miller 1980
Hunting and hawking perch					X	X	X	X					White & Raphael 1975 Gale 1973 Scott 1978
Fledging site						X	X						White & Raphael 1975
Dwelling or dens											X	X	Thomas et al. 1979 Scott et al. 1980
Loafing sites				X		X	X						Scott et al. 1980
Nesting under bark									X				Harrison 1978 Miller & Miller 1980 Scott et al. 1980
Communal nesting or nursery colonies			X							X			Scott et al. 1980 Bull 1978 Jackman 1974b Maser et al. 1981b
Anvil sites			X										Miller & Miller 1980 Swearingen 1977
Thermally regulated habitat	X	X	X		X					X		X	McComb & Noble 1981a Conner 1979a Beebe 1974

Snags as a Component of Wildlife Habitat

Snags are a vital component of the forest ecosystem (Bull 1978) providing habitat for many species of wildlife (Franklin et al. 1981) (appendix 18). The hardness of a snag is an important characteristic in determining its value for nesting or foraging. Soft and rotten snags are most used by cavity-nesting wildlife. Mannan et al. (1980), however, found that woodpeckers in the Douglas-fir forests of western Oregon often selected "hard-remnant snags" for nesting while species such as the chestnut-backed chickadee used "soft-remnant snags" (fig. 2).

Another important role of snags is the production of a rich source of foods (White & Raphael 1975). Snags are used extensively as foraging substrates by birds and mammals. Evans and Conner (1979) identified three foraging substrates provided by snags: external surface of the bark, the cambium layer, and the heartwood of the tree (fig. 3). Raphael and White (1984) found that use of snags as foraging substrate varied among wildlife species. Hairy woodpeckers and black-backed woodpeckers fed in snags 70 percent and 79 percent of the time respectively, but red-breasted nuthatches were not observed foraging in snags. As a snag decomposes, texture and moisture content of wood fibers change, which in turn affects suitability of the snag as insect habitat.

A number of avian and mammalian species use snags as food storage sites. The American kestrel, some owls, and a variety of mammals use dead trees to cache prey and other food items. Woodpecker occurrence can be limited by the absence of habitat features other than nesting snags. For example, in Monterey County, California, Swearingen (1977) found islands of suitable acorn woodpecker habitat that were not fully occupied, apparently because of a shortage of potential granary and anvil sites.

HARD SNAG SOFT SNAG

Figure 2.—Typical hard and soft snags.

FORAGING SUBSTRATE		PREY TYPE	GUILD
External surface of bark		Adult bark beetles, spiders, ants	Brown creeper, white-breasted nuthatch, white-headed woodpecker, sapsucker.
Cambium layer		Larvae, pupae	Hairy woodpecker, sapsucker
Heartwood		Carpenter ants, termites	Pileated woodpecker

Figure 3.—Foraging strategies of woodpeckers and other insectivorous birds (modified from Evans and Conner 1979, p. 217).

Natural cavities and those constructed by primary excavators in snags provide thermally-regulated enclosures for nesting and overwintering animals. Beebe (1974), Conner (1979a), and McComb and Noble (1981a), pointed out that snags provide cooler nesting substrates during hot weather periods than did open nests and artificial nest boxes. The thick walls of natural cavities moderate temperature fluctuations. This may result in increased animal survival and higher production when compared with species that nest in the open (Beebe 1974, Jackman 1974a).

Cavity-nesting species characteristically roost overnight in holes during stormy weather and during the winter (Bent 1964, McClelland 1979). Roosting in cavities may reduce winter mortality and allow a species to occur farther north than it could otherwise (Jackman 1974a). Von Haartman (1968) demonstrated that this adaptive behavior has enabled many cavity nesters to become year-round residents in a generally unfavorable winter climate. He also found that a high percentage of the permanent resident species were cavity users.

The role of snags in courtship and reproductive phases of the avian life cycle is not well documented. Bent (1964), Bull (1975) and Jackman (1974a) postulated that drumming by woodpeckers on snags or trees with dead tops is a part of some species' social behavior. Drumming was theorized to be an indispensable ritual in courtship and territorial defense and snags may be an important component in the establishment of a woodpecker's territory.

Cline et al. (1980) and Franklin et al. (1981) described the role of snag decay in nutrient recycling. Snags also act as nurture sites for trees and other vegetation (fig. 4). Snags are of primary importance in the formation of down-log habitat in streams and on the ground (see chapters 8 and 10) (Franklin et al. 1981, Juday 1978). Cline et al. (1980) stressed that the complete ecological role of snags in the forest is unclear, and that management strategies must remain flexible to ensure that future management options are not lost.

Figure 4.—Soft snag becomes a nurture site for a young tree.

Ecological Role of Cavity Users

Holes (cavities) in trees are formed in two ways: through natural decay and through excavation by woodpeckers. Both of these processes may depend on the tree being infected with fungi.

An important ecological function of woodpeckers in the forest is their role as excavators. Primary excavators are those species that actually construct nesting and foraging cavities in snags. Secondary cavity users use either natural cavities or cavities constructed by other species. McClelland (1979) indicated woodpecker hole excavation annually includes several false-start cavities that are abandoned. Some of these initial excavations, as well as the final nest cavity, provide nesting and roosting habitat for many animals. Seventeen excavator species occur in western Oregon and Washington (appendix 19).

Analysis of the Snag Resource

Snag densities, sizes, and species that occur within a forest will vary depending on the age and species composition of the stand and physical, chemical and soil factors that affect productivity of the site (e.g., aspect, elevation) (Cline et al. 1980, Manuwal and Zarnowitz 1981). These processes operate during natural development in all forest communities. Thus, characteristics and dynamics of snag occurrence often exhibit a general pattern regardless of the community in which they occur. Recognizing these patterns and understanding the processes that create them are necessary before snags can be managed successfully. In the following analysis, patterns and processes relating to snag occurrence in unmanaged Douglas-fir forests in western Oregon and Washington will be examined.

Douglas-fir forests were chosen for the analysis because information was available on snag occurrence in this type. Also, Douglas-fir forests make up a large portion of the land base in western Washington and Oregon and are scheduled for intensive, even-aged timber management (Beuter et al. 1976). As such, they illustrate the need for workable snag management programs.

The Snag Resource in Unmanaged Douglas-fir Forests

Development of Snags

The rate of development of snags, or the rate of tree mortality, varies considerably among stands of similar age, but generally decreases with increasing age (Cline et al. 1980). In healthy, young forests (stands up to 80 years old), such as those following wildfire, the development of snags is caused primarily by suppression. This results in high densities (80-320 per ac.) of small snags, usually less than 12 inches d.b.h. Suppression causes some mortality even in mature forests (80 to 200-year-old stands), but in many cases the specific cause of mortality is difficult to pinpoint. Some trees are obviously weakened prior to death by heart rot infections of the bole and/or roots (Roth, 1970), while other previously healthy trees are broken off or crushed by falling trees. These mortality factors are

less size-specific than suppression; therefore, all sizes of snags may be represented in mature forests. In old-growth forests (200+ year-old-stands), suppression is again the dominant agent of mortality in understory trees, but the mortality factors mentioned above are primarily responsible for development of the large snags and fallen trees found in old-growth forests.

Snags are also created when an old forest is converted to a young forest. Prior to the beginning of commercial logging, wildfire, insects and disease outbreaks were primarily responsible for eliminating existing forests and provided a critical link between old and new stands. As a result, young, unmanaged stands often have a variable number of large "remnant" live trees and snags (Cline et al. 1980).

Decomposition of Snags

Deterioration of snags is caused by the interaction of insects, fungi, bacteria, and weather over time (Kimmey and Furniss 1943). Five stages of deterioration of Douglas-fir snags were described by Cline et al. (1980) (fig. 5, table 2). Important trends characterizing the process of decay are (1) deterioration from top to bottom resulting in a decrease in height and sloughing of needles, branches, bark, and wood as decay advances, and (2) a general deterioration from sapwood to heartwood causing hard snags to become soft snags.

The rate of deterioration of snags depends primarily upon the size and species of the snag (Graham 1981). The process of decay is similar for large and small snags except that small snags (less than 12 in. d.b.h.) often decay and break near or below groundline (Cline et al. 1980). Because large snags require more time to decay than small snags, large snags generally remain standing longer (Cline et al. 1980, Graham 1981, Raphael and White 1984).

The species of snag is also an important factor determining longevity. Cline (1977) found that in the Oregon Coast Ranges, conifers generally lasted longer than hardwoods, and of the species of conifers examined, western redcedar and Douglas-fir were most persistent. Other factors determining the rate of deterioration are cause of death, presence or absence of heart-rotting fungi prior to death, and specific site conditions (Thomas et al. 1979). Those snags that remain standing the longest potentially provide the most benefit to wildlife, and are easiest to manage because they do not need to be replaced as frequently.

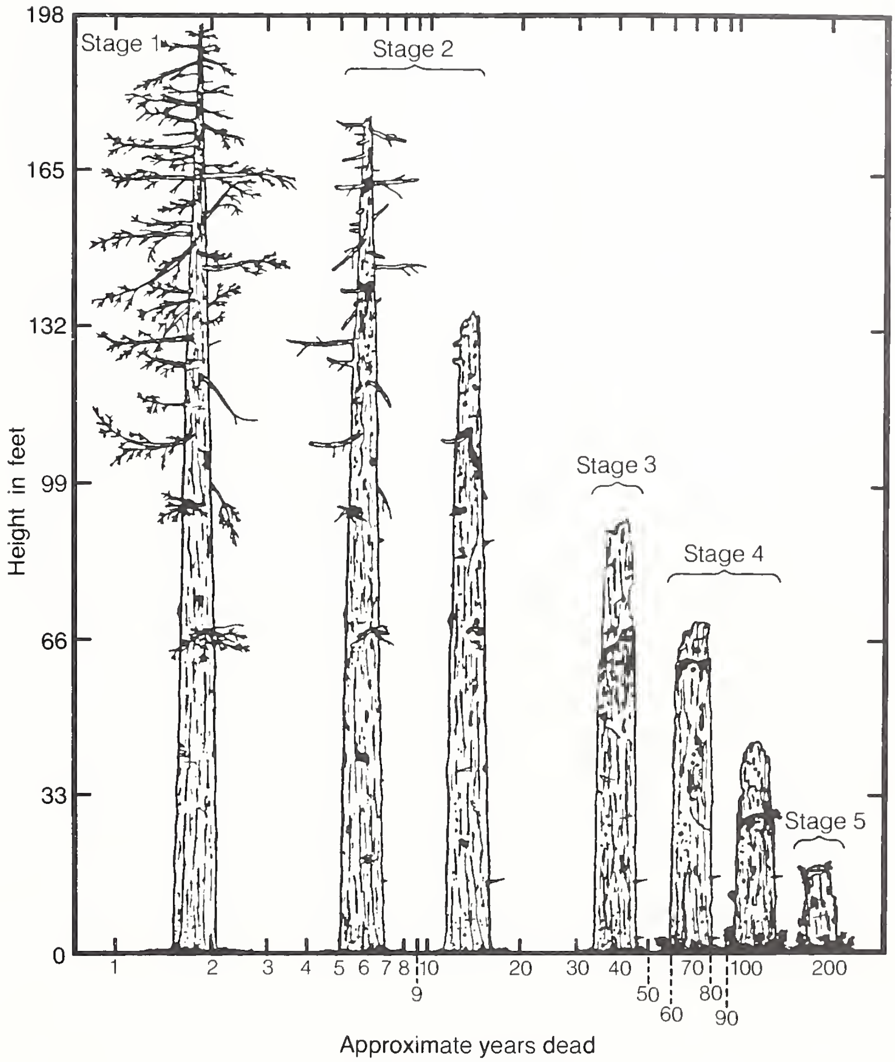


Figure 5.—Five stages of deterioration of Douglas-fir snags (adapted from Cline et al. 1980).

Table 2—Physical characteristics of Douglas-fir snags by deterioration stage, Western Oregon (adapted from Cline et al. 1980, p. 780)

Snag characteristics	Stage of deterioration				
	1	2	3	4	5[1]
Limbs and branches	All present	Few limbs, no fine branches	Limb stubs only	Few or no stubs	None
Top	Pointed	Broken			
Diameter, broken top	Increasing at decreasing rate				
Height	Decreasing at decreasing rate				
Bark remaining %	100	Variable			20
Sapwood presence	Intact	Sloughing			Gone
Sapwood condition	Sound, incipient decay, hard, original color	Advanced decay, fibrous, firm to soft, light brown	fibrous, soft, light to reddish brown	Cubical, soft, reddish to dark brown	
Heartwood condition	Sound, hard, original color	Sound at base, incipient decay in outer edge of upper bole, hard, light to reddish brown	Incipient decay at base, advanced decay throughout upper bole, fibrous, hard to firm, reddish brown	Advanced decay at base. Sloughing from upper bole, fibrous to cubical, soft, dark reddish brown	Sloughing, cubical, soft, dark brown; or, fibrous, very soft, dark reddish brown, encased in hardened shell
Estimated age at which snags reach a deterioration state:					
3.6-7.2 in. d.b.h.[2]	0-4	5-8	9-16	17	Fallen
7.6-18.8 in. d.b.h.[3]	0-5	6-13	14-29	30-60	>60
>18.8 in. d.b.h.[4]	0-6	7-18	19-50	51-125	>125

[1] Mostly remnant snags.
[2] Characteristic in Douglas-fir forests 80 years old; mean d.b.h. 5.4 ± 1.2 in.
[3] Characteristic in Douglas-fir forests 80-200 years old; mean d.b.h. 12.8 ± 2.8 in.
[4] Characteristic in Douglas-fir forests 200 years old, mean d.b.h. 38.8 ± 16.4 in.

Patterns of Snag Abundance

Snag abundance in a given stand is the result of interaction between live tree mortality and snag deterioration rates. Environmental factors that affect stand development and productivity indirectly affect snag abundance, resulting in considerable variation from site to site. Cline et al. (1980) observed changing patterns of snag abundance and characteristics as a Douglas-fir forest matured; they included (1) a decrease in snag recruitment and density, (2) an increase in average and maximum sizes of snags, and (3) an increase in the variety of snag sizes, species, and stages of deterioration. Similar patterns probably occur in other unmanaged coniferous forest types in the Pacific Northwest.

The Snag Resource in Managed Douglas-fir Forests

Much of the Douglas-fir region is programmed for intensive timber production. Timber management practices such as clearcut logging, periodic thinning, salvage, and short harvest rotation periods (less than 100 years) dramatically reduce or eliminate the potential of the forest to produce or retain the types of snags needed by many species of wildlife (Mannan et al. 1980, Manuwal and Zarnowitz 1981).

Unless management programs for snags are designed and implemented, stands under intensive timber management will contain very few snags, most of which will be too small for use by snag-dependent wildlife.

Silvicultural practices such as clearcut logging and salvage cutting often reduce or eliminate remnant snags, thereby creating a substantial gap in the supply of large snags in plantations and young forests (fig. 6). These potential conflicts can be reduced, however, by silvicultural practices that are carefully planned and implemented in coordination with snag management objectives. This section demonstrates how to predict effects of intensive silvicultural management on snag numbers through time, and discusses how one may plan for retaining snags with the size and decay characteristics needed for wildlife habitat. Although the focus will be on snag management in even-aged stands of Douglas-fir, the concepts will apply to most other conifer or conifer-hardwood forest types undergoing intensive silvicultural treatment. The following section will present a method of determining snag requirements of cavity-excavating wildlife species. Also included is a method for integrating their requirements in assessing snag numbers.

Figure 6.—A clearcut with neither live trees nor snags left. Live trees in this setting could become the large remnant snags of the future stand.

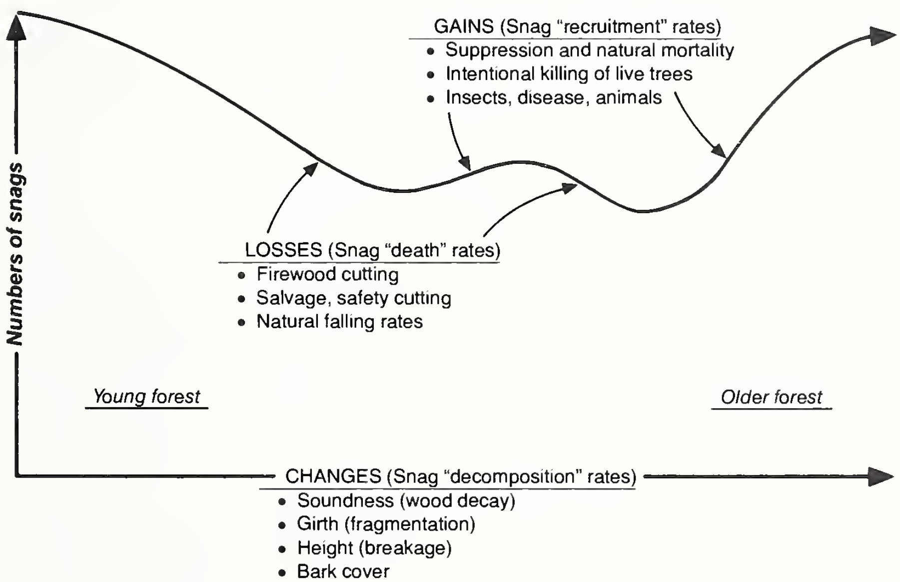


Figure 7.—Calculating snag numbers through time under even-age silvicultural management involves estimating snag gains, losses and changes. Some sources of gains and losses are shown.

Predicting Snag Numbers Under Even-Aged Silvicultural Management

The density, spacing, and distribution of snags by size and decomposition stage will change through time in forests undergoing even-aged silvicultural management. These changes are predictable given the forest management techniques to be applied. The number of snags present in a forest changes as a function of gains and losses (fig. 7). Gains result from suppression and natural mortality (fire, insects, disease) and purposeful creation of snags (girdling, topping, injection). Losses are from natural falling rates, salvage and safety cutting, and firewood cutting. Standing snags change through time in terms of decompostition characteristics, height, and bark cover (table 2). Estimating

rates of gains, losses, and changes allows prediction of snag numbers by size and decay stage throughout the life of the managed stand.

Management procedures discussed involve even-aged management of stands for wood-volume production. The stand growth model DFSIM (Douglas-Fir SIMulator, Curtis et al. 1982) is used. DFSIM generates yield tables for a variety of possible management regimes, including precommercial thinning, commercial thinning, and fertilization. The model can be used to guide stocking control and to estimate probable yields of future managed stands. Output from DFSIM includes mean d.b.h. and numbers per acre of live trees and trees dying, by five-year increments.

For demonstration purposes, assume a site index of 125, a rotation age of 100 years, a stand that will be precommercially thinned to 400 trees per acre, and commercial thinnings that will be conducted periodically (derived from table 9c, pp. 107-109, in Curtis et al. 1982). The first step in estimating snag numbers requires summarizing "gains" of snag numbers. Table 3 presents rates of snag "recruitment" from mortality by one-and five-year periods taken from the DFSIM tables. For this illustration it is assumed that snags created by means other than suppression add little to snag numbers. Suppression is the major source of snag creation in unmanaged, even-aged stands resulting from fire or regeneration harvests (Cline et al. 1980). Cline et al. (1980) reported that windthrow or uprooting accounted for less than one percent of annual tree mortality in stands less than 120 years old. Graham (1981) similarly reported that an average of seven percent (range 3-12 percent) of tree mortality in small, successional Douglas-fir was from windthrow, whereas 93 percent of tree mortality, on the average, resulted from suppression or other factors which left a standing snag.

Table 3—Snag recruitment calculated by 5-year periods for a site class 125 even-aged Douglas-fir stand managed for maximum wood volume (based on DFSIM yield and mortality Table 9c, pp. 107-109, in Curtis et al. 1982)

Stand age (years)	Snag quadratic mean d.b.h. (inches)	Mortality rates (Snag recruitment, no./100 ac)[1]	
		Yearly rates	5-year periodic rates
20-24	3.72	132	662
25-29	4.59	87	435
30-34	5.48	183	916
35-39	6.66	41	207
40-44	7.57	96	480
45-49	9.11	22	110
50-54	10.17	35	177
55-59	11.20	44	219
60-64	13.28	52	260
65-69	16.43	14	68
70-74	17.68	18	88
75-79	18.90	26	128
80-84	20.80	8	42
85-89	22.19	15	74
90-94	23.11	17	86
95-99	23.99	19	96

Stand management conditions:

- precommercial thinning at year 11 to 400 trees per ac.
- commercial thinnings at years 28, 36, 49, 66, 84
- rotation age (age at final harvest) is 100 years
- other specifications as shown in Curtis et al. (1982, p. 107)

[1] DFSIM yield tables present trees per acre (TPA) dying as rounded to the nearest tree. More precise estimates of TPA mortality (snag recruitment) may be obtained by using DFSIM's calculations of quadratic mean d.b.h. (q) and basal area (ba) of trees suffering mortality, as follows:

Yearly mortality (TPA) = $(ba)/\pi[0.5\,(q/12)]^2$. Then, multiply by 100 to obtain snag recruitment per 100 acres.

The second step is to summarize "losses" of snag numbers through time. Assume that losses arise from natural rates of falling, although intentional cutting of snags is easily added to the calculations. Cline et al. (1980) presented curves showing survival rates of Douglas-fir snags as a function of snag diameter and age. Applying their falling rates to the snags "recruited" to the forest (table 3) effectively creates a "life table" of snag numbers, as shown in table 4. A snag life table traces "cohorts" of snags through time, thus allowing one to predict snag numbers at any point along the stand growth cycle.

The first of the snag "cohorts" shown in table 4 illustrates the approach. Table 3 shows that 662 snags per 100 acres averaging 3.7 inches d.b.h. were created by suppression during the five years of stand ages 20-24. Cline et al.'s (1980) estimates of falling rates of small diameter snags suggested that after five years, about 75 percent of the original 662 snags, or 497 snags per 100 acres, would still be standing; after ten years, about 20 percent would still be standing, and so on. Thus, the fate of a snag "cohort" can be followed through time, as shown by the diagonal arrows in table 4. When the stand reaches 25-29 years old, the next set of snags (435 per 100 acres, averaging 4.6 inches d.b.h.) becomes "recruited" into the snag population. A time increment of five years was used for clarity of presentation and ease of calculation.

The third step in calculating snag numbers, once the "life table" has been established, is to estimate rates of snag decomposition. Table 2 presents Cline et al.'s (1980) estimates of snag decay rates. The stages of decay, as shown in parenthesis on the right side of each age class column in table 4, may be superimposed over the snag life table cohort sequences. Thus, reading across a row in a snag life table gives a detailed

Table 4 —A "life table" of Douglas-fir snag numbers (numbers of snags per 100 acres per 5-year increments of stand age). Numbers were calculated assuming even-aged management of a site class 125 Douglas-fir stand with no salvage removal of suppression-created snags. The column labelled "0-4" contains numbers of new snags (per 100 acres) "recruited" by suppression-induced mortality of live trees. The arrows trace the fates of each of these snag cohorts through time, showing numbers of snags still standing. The numbers in parentheses in each column shows decay stage (table 2). Therefore, reading across each row gives a detailed picture of how many snags are present at a given stand age, by snag diameter and decomposition (age) classes

Stand age (Y)	Snag d.b.h. (inches)	SNAG AGE CLASS (YEARS)										Total No. snags/ 100 acres	Average snag d.b.h. (inches)
		0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49		
0-4													
5-9													
10-14													
15-19													
20-24	3.7	662 (1)										662	3.7
25-29	4.6	435 (1)	497 (2)									932	4.1
30-34	5.5	916 (1)	326 (2)	132 (3)								1374	5.1
35-39	6.7	207 (1)	687 (2)	87 (3)	20 (4)							1001	5.6
40-44	7.6	480 (1)	155 (2)	183 (3)	13 (4)							831	6.9
45-49	9.1	110 (1)	360 (2)	41 (3)	27 (4)							538	7.7
50-54	10.2	177 (1)	83 (2)	96 (2)	6 (4)							362	9.2
55-59	11.2	219 (1)	150 (2)	22 (2)	14 (3)							405	10.6
60-64	13.3	260 (1)	186 (2)	115 (2)	3 (3)							564	12.0
65-69	16.4	68 (1)	260 (2)	142 (2)	71 (3)							541	12.7
70-74	17.7	88 (1)	68 (2)	221 (2)	88 (3)	44 (3)						509	13.8
75-79	18.9	128 (1)	88 (2)	58 (2)	195 (3)	55 (3)	35 (3)					559	15.2
80-84	20.8	42 (1)	128 (2)	75 (2)	51 (3)	156 (3)	44 (3)	21 (4)				517	15.9
85-89	22.2	74 (1)	42 (2)	128 (2)	66 (3)	41 (3)	130 (3)	26 (4)	9 (4)			516	17.2
90-94	23.1	86 (1)	74 (2)	42 (2)	128 (2)	53 (3)	34 (3)	117 (4)	11 (4)	9 (4)		554	18.4
95-99	24.0	95 (1)	86 (2)	74 (2)	42 (2)	109 (3)	44 (3)	31 (4)	52 (4)	11 (4)	9 (4)	554	20.0
100		**FINAL HARVEST**											

picture of snag numbers at a given age of the stand by snag diameter and decay stage. For example, in table 4, the stand at age 65-69 years contains a total of 541 snags per 100 acres averaging 12.7 inches d.b.h.; 68 snags per 100 acres are in decay stage 1; 260 + 142 = 402 snags per 100 acres are in decay stage 2; and 71 snags per 100 acres are in decay stage 3. Furthermore, out of the 541 snags per 100 acres total, 473 snags (260 + 142 + 71) are in the 10-15 inch diameter class, and 68 snags are in the 16-20 inch diameter class. These numbers may be compared between different snag management alternatives, and compared with estimates of different wildlife species' needs.

Effects of Even-Aged Management on Snag Numbers

The snag life table developed above may be plotted on a graph to further illustrate the effects on snag numbers from intensive, even-aged management (fig. 8). From such a graph, as from the life table, one may estimate snag numbers by diameter and decay stage at any stand age. Although this example has focused on a specific site class and management prescription, some general effects on snag numbers may be described.

First, snags induced by suppression mortality alone in a relatively short-rotation (100 years or less), even-aged silvicultural system are mostly under 20 inches d.b.h. As figure 8 shows, there may be no snags over 10 inches d.b.h. during the first half of the rotation.

Second, commercial thinnings act to reduce rates of suppression mortality. While this effect may be a positive silvicultural objective, it acts to reduce snag "recruitment" in a stand otherwise unmanaged for snags. Figure 8 shows how snag recruitment from suppression mortality (the appearance of new snag cohorts) markedly decreases following each entry. The retention of existing snags within a stand will be determined by the design of yarding corridors and safety requirements. A benefit of thinning, however, may result from accelerating tree growth to provide larger snag sizes at an earlier stand age (see chapter 14).

Third, rotation age may profoundly affect the number of large diameter (over 20 inches d.b.h.) snags present in an intensively managed stand. If final harvest is conducted at 80 years rather than 100, no large diameter snags will be present at any point in the rotation cycle (fig. 8).

Finally, snags created by suppression mortality will consistently be of smaller average diameters than the average size live tree in an even-aged stand (Cline et al. 1980). Whether this is significant for snag-using wildlife depends on each species' requirements and actual snag diameters.

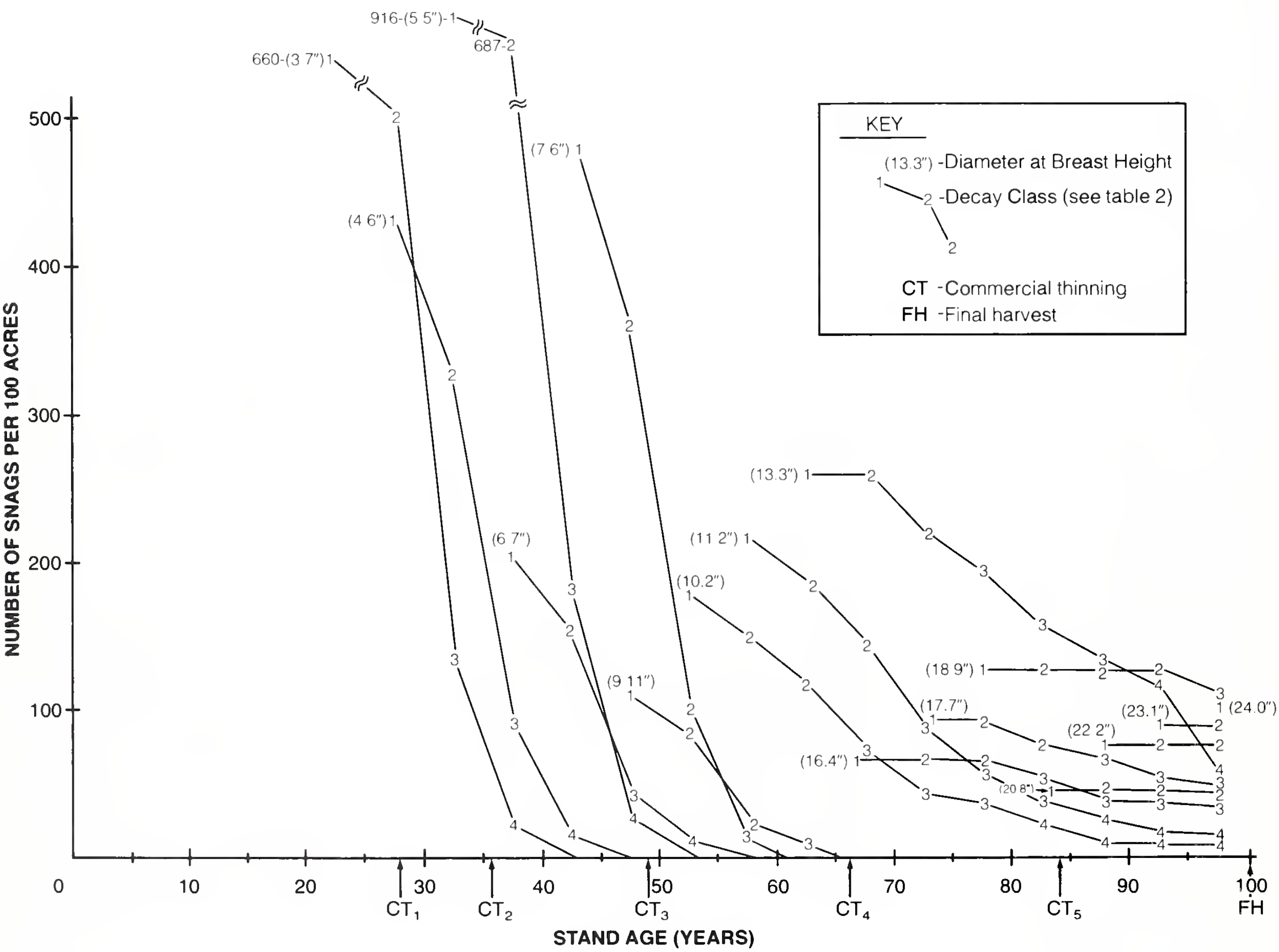


Figure 8.—Number of snags per 100 acres in an intensively managed, even-aged stand of Douglas-fir. Each curve traces the fate of a snag "cohort" shown as diagonals in table 4. CT = commercial thinning, FH = final harvest (regeneration cut).

Wildlife Snag Requirements

Patterns of Use by Wildlife

Species of wildlife that frequently use snags for foraging, nesting, or perching are selective as to size, decomposition stage, and abundance of snags. Large diameter snags are used more frequently as nest sites and also show more evidence of woodpecker foraging than smaller snags (Bull and Meslow 1977, Mannan et al. 1980, Manuwal and Zarnowitz 1981, Raphael 1980). Consequently, greater numbers of cavity-nesting wildlife are present when large snags are available than where few or no large snags exist (Balda 1975, Haapanen 1965, Mannan et al. 1980, Raphael and White 1984, Scott 1979).

In western Oregon and Washington, trees grow rapidly to large diameters. Research conducted in this region has shown that both mean and minimum snag diameters selected by cavity excavators for nesting and foraging (Mannan et al. 1980, Manuwal and Zarnowitz 1981, Zarnowitz and Manuwal 1985), are considerably larger than those reported by Thomas et al. (1979). No studies from this region have documented bird use of smaller diameter snags if larger snags are not available. Consequently, minimum snag diameters recommended in this chapter, to meet the requirements of cavity excavators and secondary cavity users (appendix 19), are larger than those recommended by Thomas et al. (1979) for the same species. All minimum size recommendations are for snag diameters measured at breast height including bark thickness.

Stage of deterioration of snags also influences use by wildlife. Each stage differs in characteristics (fig. 5, table 2), and is used in different ways by different species. In stage 1, woodboring beetles become active and woodpeckers take advantage of this source of food (Cline et al. 1980, Mannan et al. 1980). Large limbs that persist in the 1st and 2nd stages of deterioration provide perches for raptors and other birds. Stages 2-5 provide many species of wildlife with potential breeding sites. For example, the red-breasted nuthatch frequently nests near the top of snags in the 2nd stage of deterioration, while northern flickers prefer snags in more advanced stages of decay (Mannan et al. 1980). Brown creepers and some bats roost or nest behind loose bark in the 3rd or 4th stages of snag deterioration. If the requirements of all snag-dependent species are to be met, snags in all stages of deterioration need to be maintained.

One characteristic that separates the 1st stage of deterioration from the remaining four is "broken tops" (fig. 5). Broken tops are important in the decay process of both living and dead trees. Raphael and White (1984) showed a correlation between broken tops, percent bark cover and tree diameter, and densities of cavity-using wildlife species. Broken tops provide an avenue for infection by heartrotting fungi, primarily in living trees, and expose an area of heart wood to weather and insects (McClelland and Frissell, 1975). The presence of decayed heartwood is an important factor in the selection of nest sites by primary hole-nesting birds (Conner et al. 1975, 1976).

Ability of woodpeckers to excavate in snags of different soundness is related to the species' morphological adaptations for drilling (Jackman 1974b, Raphael and White 1984). Relatively strong excavators such as pileated woodpeckers are able to excavate in harder snags than the Lewis' woodpecker, a weak excavator.

Figure 9.—A snag with evidence of woodpecker foraging. Feeding holes of this size and shape are usually constructed by pileated woodpeckers.

Cavity dwellers also differ in their use of successional stages and stand structure (Bull et al. 1980, Jackman 1974b, McClelland 1977, Mannan et al. 1980, Manuwal and Zarnowitz 1981, Raphael 1980, Thomas et al. 1979). For example, the northern flicker typically nests in open situations, while the red-breasted nuthatch utilizes densely forested stands. Other structural features, such as large snags or down logs containing carpenter ants, provide a winter forage substrate for pileated woodpeckers (McClelland 1977) (fig. 9).

The importance of the species of snag with regard to use by wildlife varies with the plant community. For example, Douglas-fir snags may be used most frequently for nesting in one community (e.g., temperate coniferous forest dominated by Douglas-fir), but are of secondary importance in another community (e.g., mixed conifer forest consisting of ponderosa pine and Douglas-fir). Managers will need to determine which species of snags are most important in the forest communities under consideration.

Species-Specific Snag Requirements

To maintain populations of snag-dependent wildlife, the appropriate number, species, and size of snags in the proper stages of deterioration must be provided through space and time. Prescriptions for snag management must be handled differently for separate forest communities because the wildlife species that use each community and their specific snag requirements will be different (Thomas et al. 1979). Differences in animal species composition between the early and late stand conditions of a plant community indicates the need to provide snags in each successional stage. A procedure for calculating the snag requirements of individual species or entire communities is described below. The method builds upon the approach presented in Thomas et al. (1979) and helps the manager to select snag densities for desired population levels of snag-using species.

Table 5—Breeding or summer densities (number of birds per 100 acres) of primary cavity-nesting species (woodpeckers) reported in westside habitats. Only maximum densities reported from each reference are shown. Selected additional references from outside the westside region, mostly from the Sierra Nevada Mountains of California, are included for comparison (Other References)

Species	Shrub/open sapling-pole		Forested			
	Westside References		Westside References		Other References	
Lewis' woodpecker	—		—		12	Raphael & White 1984
Acorn woodpecker	7.7	B.G. Marcot, in prep.	3.5	B.G. Marcot, in prep.		
	20	Hagar 1960	2	Raphael et al. 1981		
Red-breasted sapsucker	2.8	B.G. Marcot, in prep.	11.3	B.G. Marcot, in prep.	2	Beaver 1972
	3	Mannan et al. 1980	0.5	Mannan 1982		
			5	Hagar 1960		
			5	Mannan et al. 1980		
			6	Raphael et al. 1981		
Williamson's sapsucker	—		0.5	Mannan 1982	2	Bock et al. 1978
					8.2	Stallcup 1968
Downy woodpecker	—		0.4	B.G. Marcot, in prep.		
			2	Raphael et al. 1981		
Hairy woodpecker	8	Hagar 1960	5.3	B.G. Marcot, in prep.	16	Raphael & White 1984
	8.2	Zarnowitz & Manuwal 1985	3	Mannan 1982	2.9	Stallcup 1968
	11	Mannan et al. 1980	4	Hagar 1960	1.2	Putnam 1983
	0.4	Morrison & Meslow 1983	6.4	Akers 1975	18	Larson 1981
			8	Anderson 1970		
			22	Anderson 1972		
			10.8	Wiens & Nussbaum 1975		
			4.9	Horvath 1963		
			3.6	Edwards & Stirling 1962		
			5.2	Knight 1979		
			16	Mannan et al. 1980		
			9.8	Zarnowitz & Manuwal 1985		
			8	Raphael et al. 1981		
White-headed woodpecker	—		1	Mannan 1982	5	Kilgore 1971
					0.8	Putnam 1983
Three-toed woodpecker	—		0.5	Beaver 1972		
Black-backed woodpecker	—		1	Mannan 1982	0.5	Beaver 1972
					1.7	Putnam 1983
Northern flicker	2.8	B.G. Marcot, in prep.	0.6	B.G. Marcot, in prep.	0.4	Putnam 1983
	12	Hagar 1960	12	Pugh & Pugh 1957		
	8	Mannan et al. 1980	0.5	Mannan 1982		
	8.2	Zarnowitz & Manuwal 1985	1	Hagar 1960		
			11	Mannan et al. 1980		
			5.4	Zarnowitz & Manuwal 1985		
			1.2	Raphael et al. 1981		
Pileated woodpecker	—		0.5	B.G. Marcot, in prep.	1.6	Tanner 1942
			0.5	Mannan 1982		
			3	Hagar 1960		
			3	Mannan et al. 1980		
			5.4	Zarnowitz & Manuwal 1985		
			0.8	Raphael et al. 1981		

In setting objectives for snag management, wildlife species-specific requirements must be determined. Estimating species' snag requirements involves an understanding of their life histories and patterns of distribution and abundance. Setting snag objectives also requires an understanding of snag dynamics in relation to use by wildlife species.

The following major assumptions were made in determining numbers of snags required by snag dependent wildlife species:

1. Meeting the needs of woodpeckers during the breeding season will also meet the requirements of most other snag-dependent species.
2. Snag requirements of woodpeckers and nuthatches is a sum of the snag requirements of individual species under consideration.
3. Primary cavity nesters will generally use larger, but not smaller, diameter snags of a given height and decay stage than those minimal diameters required. Larger snags can substitute for smaller snags, but not vice versa.
4. A given snag during a given year will be occupied by not more than one woodpecker pair, and a given snag over a number of years may be reused by the same or different species of woodpecker.

The minimal number of suitable snags (S) that must be present on 100 acres to support woodpeckers was calculated as follows: S = (D) x (C) x (X) where D = maximum density (number of woodpecker pairs per 100 acres), C = number of cavities excavated per pair per year, and X = number of suitable snags that are actually used, plus those not used but that are necessary to support the pair over the planning interval.

Maximum density. Maximum densities (D) of each woodpecker species have been estimated elsewhere by using minimum territory sizes. Raphael and White (1984) pointed out that few if any studies have actually demonstrated a minimum territory size defended by any excavator. Rather, they recommended using published estimates of species densities.

Table 5 summarizes maximum breeding or summer densities of the 11 westside species of woodpeckers estimated by various researchers. Most of the snag density values from westside habitats cited in table 3 were from surveys conducted in stands of Douglas-fir in the Coast Ranges. Species densities are presented for two major cover types: shrub/open sapling-pole stand conditions and forested stand conditions. Reasonable estimates of each species' maximum density (table 5) were used in the above formula to calculate the number of snags needed per 100 acres to support maximum densities of primary excavators (table 6), assuming that the densities represented pairs per 100 acres.

Number of cavities excavated. The number of cavities excavated per pair per year (C) by the various woodpecker species ranged from 1 to 5 (table 6). It was assumed that each cavity in a given season would be excavated in a different snag.

Suitable snags used. The correction factor (X) in the above formula accounts for numbers of potentially suitable but unused snags. Raphael and White (1984) found 3 suitable snags with no evidence of past nesting use for every 1 with such evidence. Assume that this ratio applies to each woodpecker species. Thus, the correction factor (X) should be set at 4. For example, out of 4 potentially suitable hard snags 17+

Table 6—Breeding or summer maximum densities, number of cavities excavated per pair per year, and number of snags per 100 acres needed at any given time to support maximum densities of primary cavity excavators (woodpeckers) in shrub/open sapling-pole and forested stand conditions of westside Douglas-fir habitat (maximum densities are drawn from table 5)

Woodpecker species	Max. Density (D) (pairs/100 ac)		No. cavities excavated/ pair/year(C)[2]	Snags Used (X)	No. snags needed /100 acres (S)[1]	
	Brush	Forest			Shrub/open sapling-pole	Forest
Lewis' woodpecker	—	12	1	4	—	48.0
Acorn woodpecker	10	3.5	5[3]	4	200.0	70.0
Red-breasted sapsucker	3	11.3	1	4	12.0	45.2
Williamson's sapsucker	—	8.2	1	4	—	32.8
Downy woodpecker	—	2	2	4	—	16.0
Hairy woodpecker	11	16	3	4	132.0	192.0
White-headed woodpecker	—	5	3	4	—	60.0
Three-toed woodpecker	—	0.5	3	4	—	6.0
Black-backed woodpecker	—	1	3	4	—	12.0
Northern flicker	12	12	1	4	48.0	48.0
Pileated woodpecker	—	0.5	3	4	—	6.0

[1] Formula calculation (D) x(C) x(X) = S
[2] Source: Thomas et al. (1979), Verner and Boss (1980).
[3] Five cavities per pair per year is approximated from: (14) cavities/communal group [MacRoberts and MacRoberts 1976] x (2 birds/pair) / (6 birds/group)

Table 7—Snag diameters and decay stages most often used for cavity nesting by woodpeckers (summarized from appendix 19)

Species	Snag diameter with bark (d.b.h.,inches)	Snag decay stages[1] Hard 2-3	Soft 4-5[2]
Lewis' woodpecker	17+		X
Acorn woodpecker	17+	X	
Red-breasted sapsucker	15+	X	
Williamson's sapsucker	17+	X	
Downy woodpecker	11+		X
Hairy woodpecker	15+		X[3]
White-headed woodpecker	15+		X
Three-toed woodpecker	17+	X	
Black-backed woodpecker	17+	X	
Northern flicker	17+		X
Pileated woodpecker	25+	X[4]	

Sources: Mannan et al. (1980), Raphael and White (1984), Zarnowitz and Manuwal 1985.
[1] Decay stages after Cline et al. (1980); see table 2
[2] Stage 5 snags, except those with a hard outer casing, are too far decomposed to be used for nesting by most pimary excavators
[3] May also use decay stages 2-3
[4] Will also use hard snags of decay stage 1

inches d.b.h. only 1 may be expected to be used by Williamson's sapsucker in the appropriate habitat.

Ratios of numbers of snags without cavities to numbers of snags with cavities have been found to vary widely. On the Siuslaw National Forest, surveys of snags revealed the unused:used ratio to vary from 0.3:1 to 1:1 for nesting or feeding use (C. Phillips, pers. comm.). Data from the Willamette National Forest suggested a ratio of 2:1 (E. Harshman, pers. comm.). Data from the Umpqua National Forest suggested ratios of 1.1:1 for nesting or feeding, and 6.7:1 for nesting only (Wellersdick and Zalunardo 1978). Mannan et al.'s (1980) data suggested ratios of 18:1 to 55:1 for cavity use and 0.2:1 to 32:1 for woodpecker foraging use, depending on stand age class. Ratios of unused to used snags vary by forest type and age, snag size and age, stand history, and a host of other factors (Evans and Conner 1979, Raphael 1983, Raphael and White 1984). Using the correction factor of 4 for (X) accounts for some of this variation by focusing only on snags of suitable diameters, ages, and top condition (Raphael and White 1984). This approach is recommended unless better site-specific information is available.

Using the above formula, the numbers of snags required to accommodate maximum densities of each woodpecker species were calculated for shrub/open sapling-pole and forested stand conditions (table 6). For example, in forested stand conditions of westside Douglas-fir habitat, for maximum density levels, red-breasted sapsuckers require about 45 snags per 100 acres (table 6). These must be hard snags (decay stages 2 or 3, table 2) at least 15 inches d.b.h. The value 45 snags per 100 acres was calculated from (11.3 red-breasted sapsuckers per 100 acres) x (1 cavity excavated per pair per year) x (3 suitable but unused snags plus 1 suitable and used snag).

Snag diameters and decay stages required by each excavator are summarized in table 7. Using this information, the manager can determine the requirements of each species at various population levels. Predictions can then be made regarding the impacts of various management strategies on selected species. For example, maintaining hard snags no larger than 20 inches d.b.h. would reduce or possibly eliminate pileated woodpeckers from managed Douglas-fir stands.

Numbers of snags required by each woodpecker species at different population levels can be determined from table 8. Taking direct proportions of snag levels at 100 percent population levels assumes that species densities are related to suitable snag densities in a straight-line fashion. The graphical relationship between bird and snag densities looks convex, with bird densities first increasing sharply as densities of suitable snags increase, then leveling off at higher snag densities (Raphael and White 1984, Zarnowitz and Manuwal 1985). As a useful first approximation of the relationship between bird and snag densities, a straight line is assumed until further studies clarify critical snag levels.

Table 8—Numbers of snags suitable for nesting required per 100 acres, at any one point in time, to support various percentages of maximum woodpecker densities in westside habitats (see table 7 for snag suitability criteria)

	Percent of maximum populations									
Species	100	90	80	70	60	50	40	30	20	10
SHRUB/ OPEN SAPLING-POLE HABITATS					Snags per 100 acres					
Acorn woodpecker	200	180	160	140	120	100	80	60	40	20
Red-breasted sapsucker	12	11	10	8	7	6	5	4	2	1
Hairy woodpecker	132	119	106	92	79	66	53	40	26	13
Northern flicker	48	43	38	34	29	24	19	14	10	5
FORESTED HABITATS										
Lewis' woodpecker	48	43	38	34	29	24	19	14	10	5
Acorn woodpecker	70	63	56	49	42	35	28	21	14	7
Red-breasted sapsucker	45	41	36	32	27	23	18	14	9	5
Williamson's sapsucker	33	30	26	23	20	17	13	10	7	3
Downy woodpecker	16	14	13	11	10	8	6	5	3	2
Hairy woodpecker	192	173	154	134	115	96	77	58	38	19
White-headed woodpecker	60	54	48	42	36	30	24	18	12	6
Three-toed woodpecker	6	5	5	4	4	3	2	2	1	1
Black-backed woodpecker	12	11	10	8	7	6	5	4	2	1
Northern flicker	48	43	38	34	29	24	19	14	10	5
Pileated woodpecker	6	5	5	4	4	3	2	2	1	1

Table 9 —An example of estimating snag requirements for all five westside species of woodpeckers that are found in Douglas-fir dominated temperate coniferous forests. This table assumes 60 percent population levels, and is based on information in tables 7 and 8. Numbers of snags per 100 acres are shown in parentheses. Note that snag densities shown here refer to densities through time

Snag diameter class (inches d.b.h.)	Snag decay stage[1] Hard 2-3	Snag decay stage[1] Soft 4-5	Total snags by diameter class
11+		Downy woodpecker (10)	(10)
15+	Red-breasted sapsucker (27)	Hairy woodpecker (115)	(142)
17+		Northern flicker (29)	(29)
25+	Pileated woodpecker (4)		(4)
Total snags by decay stage	(31)	(154)	(185)

[1] Decay stages after Cline et al. (1980).

Multiple Species Snag Requirements

Although the information in tables 7 and 8 can be used to estimate snag requirements of individual species, it is recommended that management programs for snags consider all snag-using species occurring in the community. Meeting the snag requirements of one species will not necessarily meet needs of another species.

The first step is to determine which cavity-using species are to be emphasized. A general guideline is to manage for excavators by westside plant community (appendix 18). The excavators found nesting in Douglas-fir dominated, temperate coniferous forests, for example, are red-breasted sapsucker, downy woodpecker, hairy woodpecker, northern flicker, and pileated woodpecker. If the objective is to manage these 5 species at 60 percent of their maximum population levels, tables 7 and 8 could be used to estimate snag densities required at any given point in time by summing these species' needs. List these 5 excavator species according to snag diameter and decomposition stage. Numbers of required snags can then be filled in, drawing from the "60 percent" column of table 8. Rows and columns can then be summed as shown in table 9. A total of 185 snags per 100 acres would be required, 31 hard and 154 soft snags. As many as 27 out of the 31 hard snags can be as small as 15 inches d.b.h. but 4 hard snags must be at least 25 inches d.b.h. to meet requirements of pileated woodpeckers. As many as 10 out of the 154 soft snags can be as small as 11 inches d.b.h. (for downy woodpeckers); as many as 115 can be as small as 15 inches d.b.h.; and the remaining 29 must be 17 inches d.b.h. or larger. A fair degree of latitude exists for targeting specific snag frequencies by diameter and decay stage. For example, larger diameter snags may substitute for smaller diameter snags, and the physical characteristics of snags vary substantially within the hard and soft decay stages. Many other management strategies may be developed, such as maintaining hairy woodpeckers at 60 percent of their maximum densitiy in stands under 60 years of age and at 100 percent in older stands.

Additional factors not explicitly considered in the above analyses of species' snag requirements include: 1) characteristics of snags used as foraging substrates; 2) management for other special habitat requirements; 3) use of sloughing bark on snags for nesting or roosting; and 4) considerations of secondary cavity-using species.

Snags as foraging substrates. A number of studies have documented that many primary cavity users forage on, within, and under the bark of live trees and snags. It is not known whether snags are an absolute requirement for wildlife species that use snags as a foraging substrate. The abundance of at least some insect species, however, is greater on and within snags than live trees.

Mannan et al. (1980) reported that diameters of snags used for foraging by northern flickers and pileated woodpeckers were greater than diameters of snags used for cavity nesting, however, the reverse trend was true with hairy woodpeckers. Raphael and White (1984) reported that snags with signs of foraging were larger in diameter than snags without sign of foraging activity. In general, it appears that excavators select the larger snags in a stand for foraging.

Acorn woodpeckers store acorns in communal "granary" trees, which are often large snags and are critical to acorn woodpeckers' habitat (Gutiêrrez and Koenig 1978). Managing snags in local clumps, as discussed below, would especially benefit acorn woodpecker communal groups.

Other special habitat requirements. The availability of suitable snags may not be the only factor limiting populations of cavity-using wildlife. Raphael and White (1984) emphasized that winter mortality may act to annually reduce populations of resident cavity nesters. Food quantity, quality, and availability may also act to limit some populations. Some bats use caves as nurseries and snags for roosting at different times of the year. Pileated woodpeckers often forage for insects in large-diameter down logs (chapter 8). For these reasons, one would not expect to find perfect correlations between breeding densities of snag-using species and densities of suitable snags, and such variability must be considered when interpreting survey and monitoring data.

Sloughing bark. Twelve west side wildlife species, use space under loose bark on snags for nesting or roosting (appendix 19). Graham (1981) estimated that the rates of snag bark loss from fragmentation of the snag bole, plus bark sloughing off the remaining bole, averaged 3.8 percent per year on large Douglas-fir stems, 5.8 percent on medium Douglas-fir, 11 percent on small Douglas-fir, 9.6 percent on large western hemlock, and 14 percent on small western hemlock. In general, bark was lost 3-6 times more rapidly from snag breakage and fragmentation than from bark sloughing from the remaining bole on Douglas-fir (3-12 times faster on western hemlock).

Rates of bark loss and sloughing may be used to roughly estimate potential remaining bark space. Bark would be lost more slowly from large diameter snags of earlier decay stages, than from smaller, softer snags of later decay stages. To help maintain bark space substrates, efforts should be made to retain large diameter hard snags with high initial bark cover.

Secondary cavity users. An assumption in this analysis is that excavator management can meet nonexcavator requirements for nest trees. Raphael and White's (1984) comparison of nest site characteristics of eight excavator species with those of seven secondary cavity-using species suggested that the assumption is valid, except for brown creeper. Brown creepers' requirements for nest sites are not met by managing for excavators. The needs of this species for large snags and trees with sloughing bark and natural cavities should be explicitly added to excavator management plans. Also, special planning may be required to insure availability of large natural cavities used by several other secondary cavity users such as Vaux swift, raccoon, and black bear (see appendix 19).

Estimating snag numbers needed by a particular species at a specified population level has addressed snag densities at only one point in time. Additional provisions must be made for rates of snag loss, changes in wildlife snag suitability (because of decomposition), and changes in species densities and requirements through a successional series.

Managing Snags Through Time and Space

Snag requirements discussed above (tables 6 and 8) are based on the premise that snags of suitable sizes and densities will be maintained through time. Retention of snags and maximum production of wood fiber are divergent goals (Jackman 1974b).

Unless large snags receive special consideration, they will be eliminated from stands undergoing intensive silvicultural management because of conflicts with silvicultural systems, logging systems, and fire and safety regulations (table 10). Periodic thinning, salvage, and sanitation logging reduce or preclude formation or retention of dead and defective trees (Cline 1977). Elimination of decaying and decadent trees can occur within one rotation period and will result in a dramatic decrease in cavity nesters (Dickson et al. 1983).

Rising demand for fuelwood is increasing the rate of snag removal. In their Michigan study area, Dingledine and Haufler (1983) reported that new snag generation and the presence of certain snags unsuitable as fuelwood was all that prevented a complete removal of existing snags. They found that fuelwood cutters normally prefer hard snags in an early stage of decomposition. Extensive hard snag removal for fuelwood will negatively impact hard snag-using species in the short run and soft snag-using species in the long run.

Intensive timber management also affects cavity dwellers through a general trend towards habitat simplification (Beebe 1974). This includes a reduction in tree species diversity (Beebe 1974, Jackman 1974b, Meslow 1978), a narrower range of stand structures, and a reduction in forage insects because most dead wood is removed (Cline 1977, McClelland 1977). Additionally, trends toward elimination of older stands, shortening of grass-forb and brush-sapling stages, alterations of riparian habitat, and the conversion of hardwood stands affect habitats important to snag-dependent wildlife (Jackman 1974b, Meslow 1978).

Woodpeckers have specific morphological adaptions and specialized foraging behavior which results in selective habitat use. This suggests a partitioning of breeding and foraging resources

Table 10 —Forestry practices that usually impact snag production and retention (modified from McClelland, 1977, p. 330-331)

Forest Practice	Potential Adverse Impact		
	None to slight	Moderate	High
Silvicultural system	Single-tree selection Extended rotation	Group selection, shelterwood	Clearcutting with short rotations
Utilization standard	All snags and culls retained	Some snags and cull trees retained for wildlife	Intensive salvage program
Harvest method	Balloon or horse logging	Skyline full-suspension	Cat logging, extensive road system
Dead wood (fuels) management	No burn	Spot burn	Broadcast burn, preventive fire management
Fuelwood harvest	Highly restricted and regulated	Restricted to specific areas	Few restrictions, low regulations
Herbicides	No treatment	Spot treatment with surface equipment	Aerial application (snags felled for aerial access)

which, in turn, acts to reduce interspecific competition among sympatric species (Bull et al. 1980, Jackman 1974b, Raphael 1980). The implication to snag management is the necessity of providing a full range of snag and stand conditions throughout succession if cavity dwellers are to be managed as a group within a plant community.

Methods of Providing Snags

Methods available to maintain snags on commercial forest land include: 1) long rotations of stands; 2) long rotations of selected groups or individual trees; 3) artificial creation of snags; and 4) the retention of snags in managed stands (Thomas et al. 1979). The feasibility and effectiveness of these methods are, in turn, influenced by silvicultural systems and the intensity of timber management practices.

Long Rotations of Stands

Managing forest stands over long rotations produces both large snags and older forests. In addition to offering optimum habitat for most cavity dwellers, long rotations may help maintain older forest stand conditions for users of large snags such as Vaux's swift and spotted owl (Forsman 1980, Franklin et al. 1981).

Areas managed on long rotations may provide snag densities near the 100 percent level, thereby reducing the number of snags needed on nearby areas managed intensively for timber production under shorter rotations. The harvest of old stands managed under long rotations (providing salvage operations, partial cutting, and thinning do not significantly reduce densities of desired snags) can provide a source of large remnant snags, natural cavities, and down logs. Stands managed on long rotations provide the most secure locations for snag maintenance through time.

Long rotations, as a method to maintain snag-dependent wildlife, are compatible with management of lands of limited timber potential, or with other management objectives involving older forests. These may include: 1) maintaining old stands to retain the functional and compositional features of old-growth forest (Franklin et al. 1981); 2) providing the requirements of threatened, endangered, or mature-stand species such as the spotted owl or bald eagle (Forsman et al. 1982, Juday 1978); 3) obtaining benefits from streamside or visual corridors (Cline 1977, Franklin et al. 1981, Mannan 1977); and 4) maintaining optimal cover for deer and elk (chapter 11).

Long Rotations of Individual Trees or Groups of Trees and Snags

Long rotations of selected trees or groups of trees and snags represent another option to maintain and produce large trees and ultimately large snags. This option is used appropriately when older forests are converted to plantations with shortened rotations and smaller trees, thereby providing snags following clearcutting. Snag management via groups of trees has several advantages: 1) clumps of snags are often preferred sites for nesting; 2) grouping snags may promote energetically efficient foraging by woodpeckers (Raphael 1980); 3) groups of snags may provide hole nesters some protection from predators (McClelland 1977); and 4) clusters of trees distributed over an area can be maintained more easily than scattered individual snags (Cline 1977). One option is to allow these patches to develop under uneven-aged management to provide a continuing recruitment of snags of suitable size and achieve a mix of decay stages (Raphael 1980).

Size and state of decay are important characteristics in selecting live trees and snags to retain. Large snags stand longer and are suitable for use by more species than are small snags (Mannan et al. 1980). Live trees showing signs of decay such as butt rot, broken tops, fungal conks, dead branch stubs, or other defects, as well as snags with existing cavities, are potential candidates for nest sites (Bull et al. 1980, Conner 1978, Kilham 1971, McClelland et al. 1979) (fig. 10). Broken top trees are

less subject to windthrow (Raphael and White 1984, Scott et al. 1980) and shorter snags (less than fifty feet tall) create fewer operational conflicts (Cline 1977). Woodpeckers, however, partition snag use on the basis of height and, where possible, tall snags should be left (Raphael 1980). Similarly, the retention of snags representing all stages of decay provides for cavity dwellers as a group (Cline 1977). Indications of wildlife use such as those illustrated in figure 11 can assist in the selection of snags or green trees for retention.

Figure 10.—A broken-top cull (green tree) is potential wildlife nesting habitat.

Both individual and groups of large trees and snags are exposed to the full range of potential conflicts with logging systems and fire and safety regulations during logging and silvicultural operations. Consequently, leaving snags and live trees in patterns that minimize operational conflicts is necessary if snags are to be retained in managed forests over extended periods of time (Cline 1977). Potential leave sites often include draws and the edges of management units. To meet selected levels of management, patches should be distributed to provide the needs of the wildlife species with the smallest territory requirements.

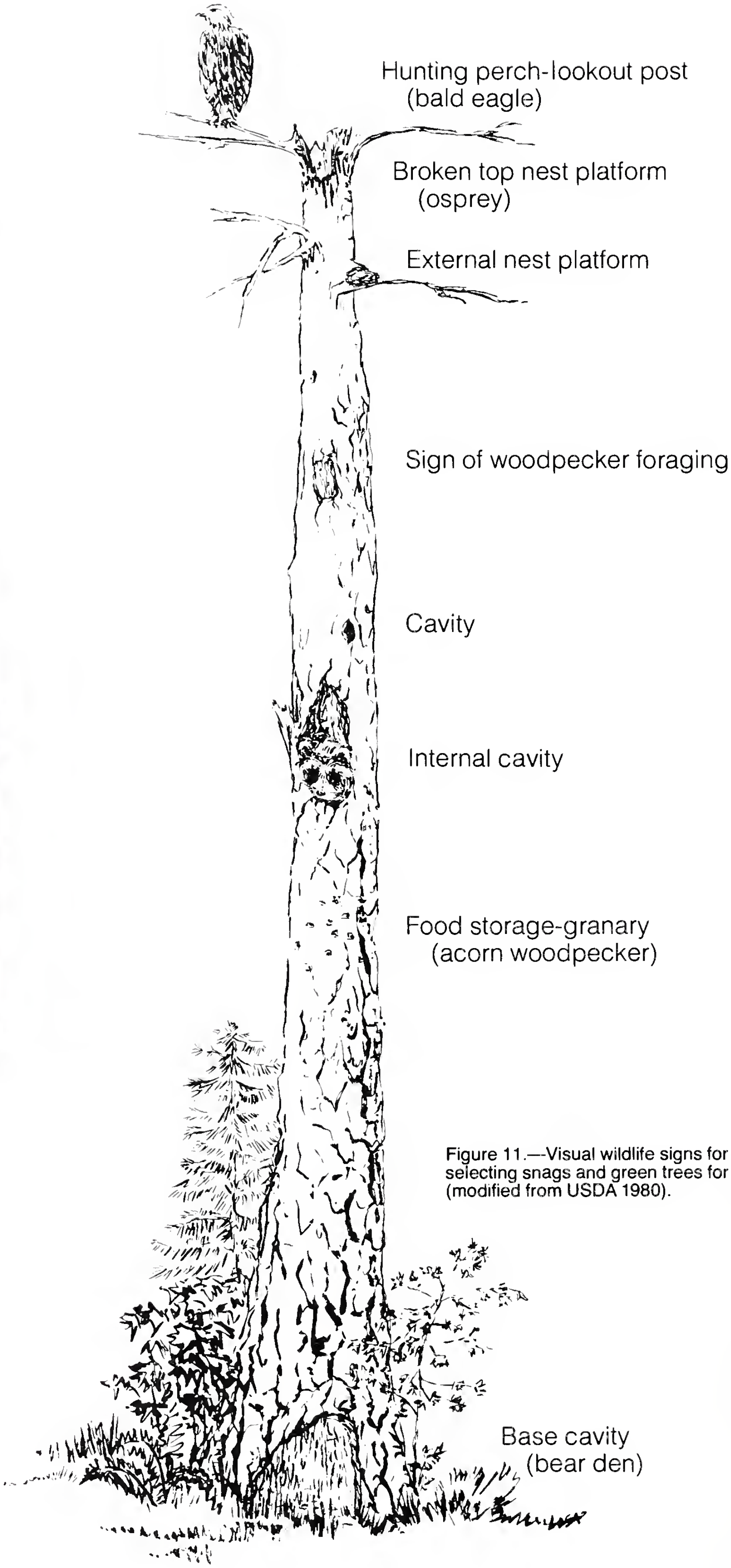


Figure 11.—Visual wildlife signs for use in selecting snags and green trees for retention (modified from USDA 1980).

Artificial Creation of Snags

Creating snags by intentionally killing living trees is a possible means of increasing the density of snags suitable for use by primary excavators (Conner et al. 1983). One advantage of this method is that location and timing can be selected in advance. Artificial snag production may be necessary to supplement snag recruitment and retention on lands managed intensively for timber.

Topping trees to provide an avenue for entry by heart rot may increase their potential for nesting (Bull et al. 1980). Woodpecker preference for nesting near the top of broken-top snags has been widely noted; snags decaying from the top downward are likely to produce a succession of sites suitable for excavation as the snag decreases in height over time (fig. 5). Blasting tops out of cull trees prior to clearcut harvest has been economically accomplished within safety codes (Bull et al. 1981, Lint 1981, U.S. Department of the Interior 1981), (fig. 12).

Figure 12.—Blasting the top out of a green cull tree to produce a future snag.

Snags produced by girdling live trees may have a low potential as suitable nest sites. Girdling may promote decay from the outside in, resulting in a snag with relatively firm heartwood surrounded by decayed sapwood (Miller and Miller 1980). Also, initiation of decay in the lower bole may produce a snag that will fall before suitable decay conditions develop in the upper bole.

Boring and inoculating the heartwood of selected trees with a suitable fungus at appropriate heights mimics the initiation of decay from branch stubs and parallels the conditions produced in broken-top trees (Conner et al. 1983). The method may also shorten the time interval to reach desired decay conditions, and has the advantage of controlling fungal agents, not all of which produce a suitable decay condition for excavation (Conner 1978, Jackman 1974b).

Herbicides present another possible method to create snags in a coniferous forest, but their effect on heart rot fungi and insects associated with dead wood needs to be examined (Conner 1978). The effect may be similar to girdling if the tree is drilled in a series of locations around the trunk and injected with herbicides. The resulting snag may fall before it becomes suitable for cavity excavation. With hardwoods, however, Conner et al. (1981) found that the injection of herbicides could provide future woodpecker nesting and foraging sites.

Retaining Snags in Managed Stands

Once the desired level of snag habitat has been determined, implementation of snag management requires consideration of the needs of both wildlife habitats and wood products to achieve multiple objectives. In addition to providing snags during timber harvest and subsequent silvicultural operations, there is a need to provide target snag requirements through time.

As a basis for planning snag management through time, the manager needs to know:

1. The existing forest land base: The forest is usually divided into areas that will receive similar types of management based on age class. It is necessary to know the proportion and amount of the land base that will be managed under extensive and intensive management regimes, and the types and intervals of treatments. These parameters directly affect the size, number, and dynamics of snags available for management.

Within each forest management area, the proportion, amount and distribution of each stand condition also needs to be known in order to determine current and future habitat conditions.

Additionally, each combination of land allocation and stand condition represents a different set of conditions for snag maintenance or development.

2. Current condition, management objectives, and the time frame of implementation: These factors determine the intensity of snag management required. Tradeoffs are implicit in the timing and cost of implementing snag requirements. The forest manager must evaluate both cost and the current population level of snag-dependent wildlife when designing strategies for snag management. Importantly, existing snag densities on portions of forests may already be below the minimum required level to maintain viable population levels of snag-dependent wildlife species.

3. Snag dynamics: Information concerning rates of snag recruitment, fall, and decay processes is necessary for the development of procedures to ensure that habitat for cavity users will be provided through time. The data should be as specific as possible for the land types under consideration. Current intensive timber management practices are relatively new and treated stands will differ markedly from natural stands. Estimates may have to be made based upon the best available information. Published literature, permanent forest sample plot data, local studies, and periodic timber inventories are good sources of information. In many cases, it may be possible to acquire the needed data during scheduled timber reinventories.

4. Snag quality: The appropriate size, condition, and density of snags and the surrounding environment combine to form the habitat available for use by snag-dependent wildlife. It is important that the combined result of these parameters are periodically evaluated by forest managers to ensure achievement of snag management objectives.

This section is based on the earlier example developed to predict snag numbers in an even-aged stand of Douglas-fir, where recruitment of snags came only from suppression, and is extended to show how a manager may assess effects on snag numbers by considering some of the management options discussed above.

To meet snag management objectives through time and space, the manager must go beyond the single stand level in assessing overall snag densities. Adjacent stands may be managed under similar or different objectives, and their composite effects on snag numbers must be considered. The effects of snag distribution and abundance should be evaluated at the level of a management unit or compartment, which may average roughly 2,000 to 10,000 acres. This scale of assessment takes into account harvest scheduling, with final harvests of different stands staggered in time. The example also illustrates how leaving snags at final harvest is necessary to provide snags through the early stand conditions of the next stand rotation.

Step 1 — Define stand management prescriptions. The example assumes that three adjacent stands of Douglas-fir, as described in table 3, will be managed intensively under an even-aged system. In stand 1 (50 acres), snags present at final harvest will be retained. In stands 2 (60 acres) and 3 (30 acres), all snags will be removed at final harvest. Throughout the growth of the three stands, 40 percent of all snags will be removed during commercial thinning operations. (This is equivalent to multiplying all values in table 4, and values on the vertical axis of figure 8, by 0.6; that is, 60 percent of all snags will be retained.) It is assumed that final harvests of the forest stands will be staggered evenly through time; stand 1 is clearcut at year 0, stand 2 at year 33, and stand 3 at year 66, with all three stands having rotation ages of 100 years. It is also assumed that, for the first 19 years following final harvest, a stand is in a grass-forb/shrub/open sapling-pole stand condition. Note that this example does not specifically call for artificial creation of snags and retention of green trees for future snags.

Step 2 – Predict snag densities through time over all stands. Figure 13 illustrates the recruitment and mortality rates of snags in all three stands. Staggering final harvests also staggers snag recruitment in this three-stand perspective. The number of snags present by diameter and decay stages in each stand, as was illustrated in table 4, should now be tallied. Note that snags retained at final harvest in stand 1 carry through the first half of the next rotation cycle, although in decreasing numbers as the snags fall.

The density of snags in a stand at any one time is multiplied by the stand area, and this product is summed over all stands. The result of this calculation is a table showing snag densities by diameter and decay stage (hard vs. soft) for both open and forested stand conditions, averaged over the entire area occupied by all stands (table 11). In the first five-year interval, for example, stand 1 (providing open stand condition habitat) contributes 81 hard plus 18 soft snags to the 99 snags per 100 acres average. Stand 2 (providing forested stand condition habitat) contributes 121 snags per 100 acres average, all hard snags. Stand 3 contains no snags 11 inches d.b.h. or larger.

Step 3 – Compare snag densities to species' requirements. Densities of snags tallied by diameter and decay stage and by stand condition in which they occur (table 11) may then be compared to excavator species requirements (tables 7 and 8). Species' requirements in forest stand condition habitat will be assessed. It is assumed that a woodpecker species that requires larger diameter snags will preclude a second species that requires smaller diameter snags from using large snags, if numbers of small snags are insufficient for supporting the second species at a 100 percent density level.

During years 25-29 (table 11), for example, 107 (98 + 9) hard snags per 100 acres 15 inches d.b.h. or larger would meet the 100 percent requirement for red-breasted sapsucker. Twenty-three soft snags per 100 acres 17 inches d.b.h. would be used by northern flickers. Table 8 shows that 23 (suitable) snags per 100 acres would meet 50 percent of the northern flickers' nesting requirements. Similar comparisons with the smaller diameter soft snags would allow the land manager to estimate the percent of nesting snag requirements for hairy and downy woodpeckers that would be met by this type of forest management regime.

It is essential that snag diameter and decay stages be included in assessing a woodpecker species' habitat requirements. In years 0-4, 121 total hard snags per 100 acres is the average density; but all 121 are too small for pileated woodpeckers, and most are too small for red-breasted sapsuckers. Time is also a crucial element. Table 11 shows that nesting snag requirements in forested habitats for red-breasted sapsuckers are at or above the 40 percent level throughout the stands' rotations, except for years 35-39, when only 20 percent of the species' requirements are met. Adequate densities of snags of each diameter, height, and decay stage required by different species must be present through time if specific management objectives are to be fulfilled.

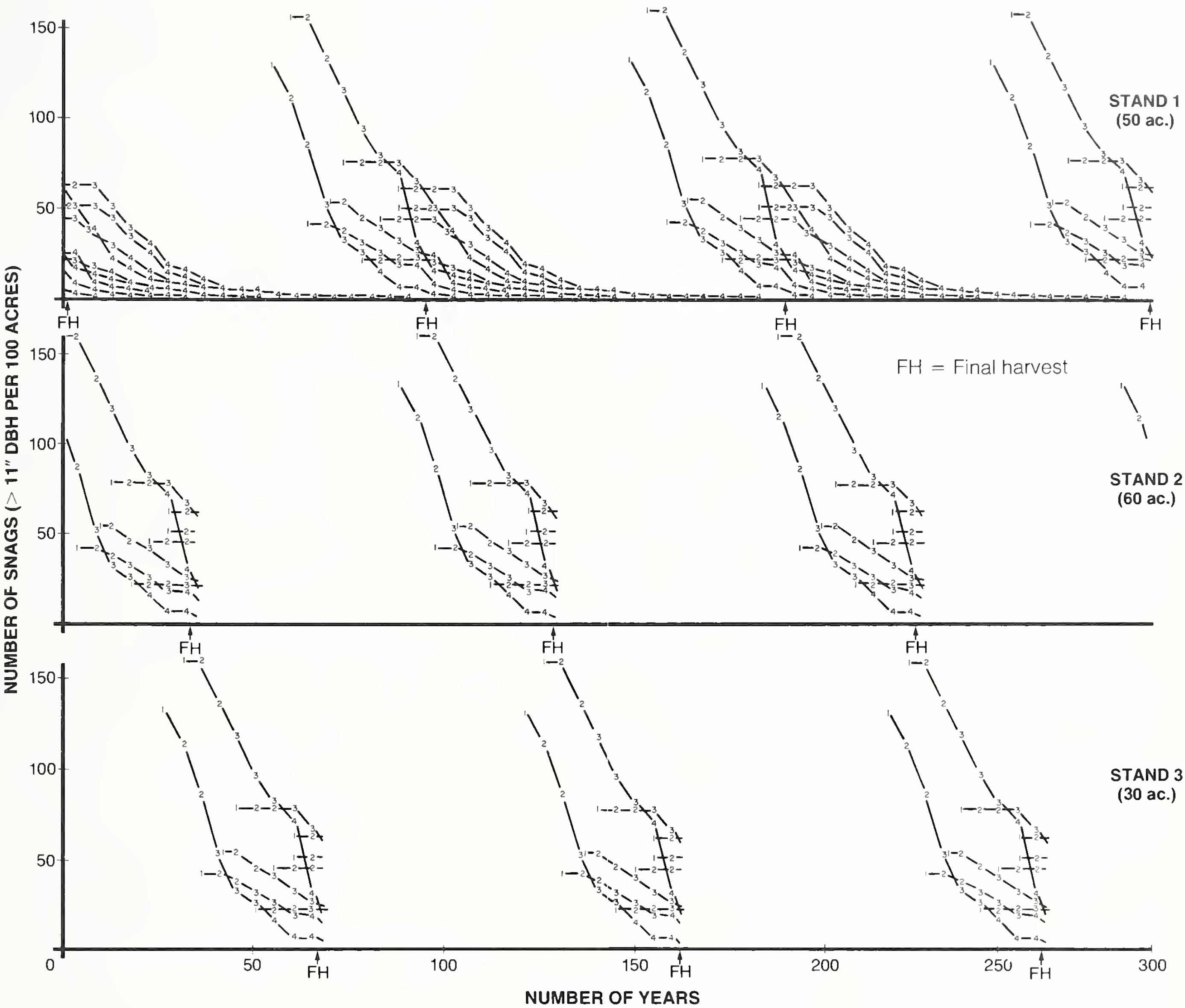


Figure 13.—Number of snags per 100 acres in three intensively managed, even-aged stands of Douglas-fir with staggered final harvests (FH). As in figure 8, each curve traces the fate of a snag "cohort" (numbers along each curve represent snag decay stages as in table 2).

This example was designed to demonstrate: 1) that predicting snag densities by size and decay stage is possible; 2) that leaving snags at final harvest may help meet some of a species' requirements through the first stages of the next rotation; 3) that staggering final harvests of adjacent stands through time allows a broader area to retain snags; 4) that averaging snag densities over a management compartment is a useful scale for assessing snag objectives; and 5) that assessing the percentage of species' nesting snag requirements met by a specific forest management regime must take into account a time dimension and size and decay stages of snags. The final step in meeting snag management objectives would be: a) to calculate snag densities by size and decay stage needed to meet specific excavator population levels (table 9); b) to "plug" these minimum snag densities into a snag life table to ensure these minimal snag densities are present through time; and c) to "work backwards" through stand growth and yield tables (e.g. DFSIM, Curtis et al. 1982) and snag survivorship (falling rate) estimates, to determine numbers of green trees and snags by diameter class to retain at various years, so that snags may be created and retained at appropriate times.

Table 11 —Average number of snags per 100 acres over time by decay and diameter class (derived from the example of forest stand management presented in figure 13). Also shown is the percent of maximum habitat requirements that this number of snags would provide over time for five woodpecker species that use forested habitats

TIME, YEARS →

	Snag Decay Stage	D.B.H. (in.)	0-4 (1)	5-9 (2)	10-14 (3)	15-19 (4)	20-24 (5)	25-29 (6)	30-34 (7)	35-39 (8)	40-44 (9)	45-49 (10)	50-54 (11)	55-59 (12)	60-64 (13)	65-69 (14)	70-74 (15)	75-79 (16)	80-84 (17)	85-89 (18)	90-94 (19)	95-99 (20)
Average no. snags per 100 acres — FOREST	Hard	≥25	0 →																			
		≥ 17,<25	0	23	56	63	94	98	116	0	11	28	31	40	49	58	19	46	52	66	82	96
		≥ 15,<17	18[1]	17	15	14	11	9	0	9	9	8	7	5	4	15	15	13	11	9	7	0
		≥ 11,<15	103	80	64	51	32	28	57	51	40	32	26	64	96	86	66	54	43	28	56	115
		TOTAL	121	120	135	128	137	135	173	60	60	68	64	109	149	159	100	113	106	103	145	211
	Soft	≥25	0 →																			
		≥ 17,<25	↓	↓	↓	↓	20	23	16	12	9	8	8	6	5	4	3	2	1	1	0	0
		≥ 15,<17	↓	↓	↓	↓	1	1	9	0	0	0	0	0	0	4	0	0	0	0	0	7
		≥ 11,<15	↓	↓	↓	↓	9	35	17	1	0	0	0	4	17	8	0	0	0	5	28	13
		TOTAL	0	0	0	0	30	59	42	13	9	8	8	10	22	16	3	2	1	6	28	20
Average no. snags per 100 acres — BRUSH	Hard	≥25	0 →																			
		≥ 17,<25	81	59	47	30	0 →															
		≥ 15,<17	0	0	0	0	0 →															
		≥ 11,<15	0	0	0	0	0 →															
		TOTAL	81	59	47	30	0 →															
	Soft	≥25	0 →																			
		≥ 17,<25	9	18	15	17	0 →															
		≥ 15,<17	3	1	1	1	0 →															
		≥ 11,<15	6	5	4	3	0 →															
		TOTAL	18	24	20	21	0 →															
Percent of maximum nesting requirements provided by snags in the forested habitat	Hard snag users	Red-breasted sapsucker	40[2]	90	100	100	100	100	100	20	40	80	80	100	100	100	80	100	100	100	100	100
		Pileated woodpecker	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Soft snag users	Downy woodpecker	0	0	0	0	55	100	100	10	0	0	0	25	100	50	0	0	0	30	100	80
		Hairy woodpecker	0	0	0	0	<10	<10	<10	0	0	0	0	0	0	<10	0	0	0	0	0	<10
		Northern flicker	0	0	0	0	20	25	20	10	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	0	0

[1] Example of calculation: 18 hard snags 15-17 inches d.b.h. per 100 acres average in forested habitats = (0 snags per 100 acres X 0 acres of forested habitat in stand 1) + (42 snags per 100 acres X 60 acres in stand 2) + (0 snags per 100 acres X 30 acres in stand 3), all divided by 140 acres total.

[2] Example of calculation: red-breasted sapsucker requires hard snags at least 15 inches d.b.h. (table 8). During the 0-4 year time period, there are 18 snags (in forested habitat) per 100 acres (see footnote [1]). Table 9 shows that this snag density corresponds to a level of 40 percent of maximum density of red-breasted sapsuckers.

Distribution Patterns of Snags over a Landscape

The more land managed for higher woodpecker population levels, the greater the probability that viable populations of snag-dependent species will continue to exist in an area. The tradeoff between managing many acres at low snag densities and few acres at high snag densities is a difficult one to assess. If suitable snags are widely distributed (i.e., at very low densities), snag-using wildlife may not find enough snags for nesting, roosting, or foraging within their territory, home range, or dispersal distance. On the other hand, if suitable snags are highly aggregated in local groups, fewer wildlife species may be able to breed, feed, or roost in them without intra- and interspecific crowding. Also, long distances between highly aggregated snag groups may prevent some wildlife species from more fully occupying an area than if a more even dispersion of snags were present.

It is unlikely that snag management can be uniformly applied across a land base. Managing very large areas at very low snag densities and, conversely, managing for very high snag densities on only a few areas should be avoided. Over a large land base, balancing local snag groups with more widely distributed but lower densities of snags, may be a useful approach. Raphael and White (1984) recommended providing snags in dispersed clumps rather than as single trees uniformly distributed over an area.

Snag patches may be preferred by birds for nesting and foraging. Closely spaced large snags may allow maximum energy intake, partly by reducing intertree flight time and distance (Raphael and White 1984).

Buffers or leave strips of old, large trees and snags along riparian/wetland zones (chapter 4), or a good distribution of small clumps of older trees with abundant snags within younger forest stands, would be of great value (Evans and Conner 1979). Zeedyk and Evans (1975) recommended leaving a one-fourth acre clump of trees within each 5 acres of regeneration in deciduous forest. The arrangement of these clumps could be flexible; combining four clumps would give a one-acre patch of mature forest with large diameter snags in each 20 acres of young (regeneration) timber (Evans and Conner 1979).

Raphael and White (1984) suggested that to maintain foraging substrates, manage for one clump of 15 closely spaced snags over 9 inches d.b.h. every five acres. Clumps consisting of fewer than 15 stems should be spaced closer together. Clump density, however, should not be lower than one clump per five acres.

Guidelines for Selecting Wildlife Trees to Meet Logging Safety Requirements

State Workmen Compensation Laws and O.S.H.A. rules require that a safe work area be provided for forest workers during timber harvest activities. State of Oregon Safety Codes require felling of a danger tree which is leaning toward and within reach of landings, haul roads, rigging, or work areas. In general, a danger tree is any standing tree, live or dead, that presents a hazard to woodsworkers. The Oregon safety code requires that danger trees be felled or work activities arranged so that woodsworkers are in a safe position at all times.

More standing-dead or live-defective trees than will ultimately be needed for snag or cavity-using wildlife habitat should be selected by the manager during timber harvest planning. This will allow removal of questionable trees (in relation to logging safety) prior to harvest activities while still maintaining enough trees for wildlife. The question of safety of a particular tree will be determined by the loggers, timber sale representatives, and/or safety inspectors.

The following guidelines for identifying potential standing-dead or live-defective (cull) trees for wildlife habitat are intended to provide selection criteria that are compatible with industrial safety (USDA 1960).

Snag Specifications for Logging Safety

1. The following snag species are listed in order of increasing hazard from a safety stand point:

   a. Douglas-fir (least hazardous)
   b. Ponderosa pine
   c. Lodgepole pine
   d. True firs and hemlock
   e. Larch
   f. Cedar
   g. Hardwoods and other species (most hazardous)

Cedar snags usually remain standing longer than Douglas-fir and other tree species in unmanaged stands. In harvest units, however, these cedar snags often become danger trees because of weakened portions of their trunks.

2. Trees with a d.b.h. of 12 inches or less tend to be more hazardous than larger trees. Root masses on small trees are usually not well developed and deteriorate quickly causing the stem to become unstable. Trees with diameters greater than 12 inches are preferred but smaller trees could be selected after careful study of the tree's stability. Trees with broken tops and less than 60 feet tall are most desirable from a logging safety viewpoint.

3. Trees with substantial lean should not be selected in areas where woodsworkers will be active. The more vertical a tree stands, the more desirable it is from a worker's safety viewpoint.

4. Other factors to consider are soil depth, quality of remaining root structure, and slope of the terrain. These factors should be evaluated on a case-by-case basis. Shallow soils over solid rock produce shallow root wads that are usually less stable than root wads developed in deep soils. The quality of the remaining root system of a snag has a direct effect on the stability of the snag. Trees that have few sound roots or died from a root-rotting disease should not be selected. The slope of the terrain affects how far a snag will slide or roll if it falls. Snags falling on slopes may travel farther than the length of the snag.

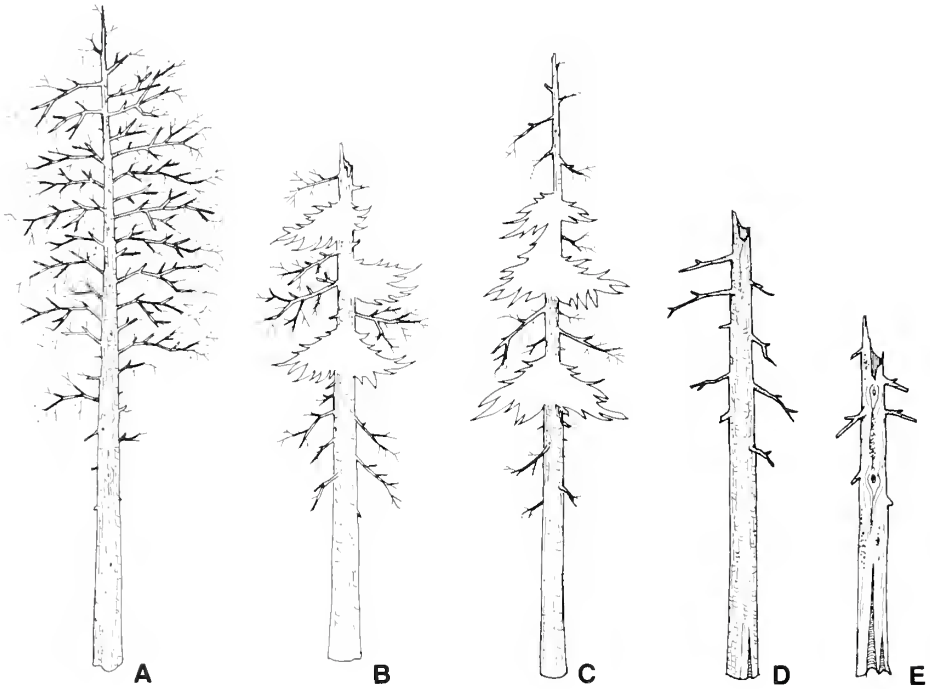


Figure 14.—Snag types that may be compatible with logging operations. See text for descriptions.

Snag Types that are Compatible with Logging Operations

Standing-dead or live-defective trees that are most preferred from a logging safety standpoint are:

Type A. Trees that have recently died and have good root systems. Needles are red and some are still attached to the tree (fig. 14-a). Trees with little or no lean are best. Trees with tops already broken out or are suitable for topping are also preferred;

Type B. Live cull or defective trees that are windfirm and have tops broken out at ½ to ⅔ of tree height (fig. 14-b);

Type C. Live-defective trees that are deemed safe to be topped (using explosives) to reduce susceptibiltiy to blowdown after harvest (fig. 14-c). Some device will be required to raise workmen or explosives to the selected height for topping. Climbing of defective trees for placing explosives should be done in accordance with all safety regulations governing the locale of the trees. Selected trees should be stable and have as little lean as possible;

Type D. Snags that are over 12 inches d.b.h. with bark still tight, preferably with tops broken out, and with slight or no lean (fig. 14-d); and

Type E. Snags with tops broken out and with loss of bark evident (fig. 14-e). Lean must be away from work areas, or preferably, the snags should stand straight and be less than 60 feet in height.

Locations of Snags for Safety

Snags are best left along natural or man-made openings. For leaners, the lean should be into the clearing or along the edge away from timber harvest activity. Snags can be left along lakes, ponds or streams especially where the lean is over the water or along the edge away from work areas. On lakes with high recreational use, consider human safety when designating snags for retention. Riparian zones (see chapter 4) and ravines are also possible locations for leaving snags (fig. 15). Because of the multi-resource values of riparian zones, they are well suited for long-term snag retention.


Figure 15.—Snag group selection in a riparian zone.

Snag Considerations Under Various Management Practices

Clearcutting. Manage for snags along boundaries or in clumps (figs. 16 and 17). Snags can be more evenly distributed on clearcut units located on moderate to flat terrain which are scheduled for tractor yarding. Individual wildlife trees retained in the interior of clearcut units should not exceed 60 feet in height. Shorter trees lessen conflicts with yarding and fewer cable roads are required to avoid damage to the leave trees. Retain individual trees, snags, and/or live-defective trees along boundaries between adjacent clearcut units (fig. 18) (USDA 1982). These trees should be located in the lower one-half to two-thirds of each unit (USDA 1982) (figs. 19 and 20). Explicitly plan not to harvest boundary trees and snags when the adjacent stand is cut.

Figure 16.—Clumped green wildlife trees within a clearcut.

Figure 17.—Retained snag groups within and on the boundary of a clearcut.

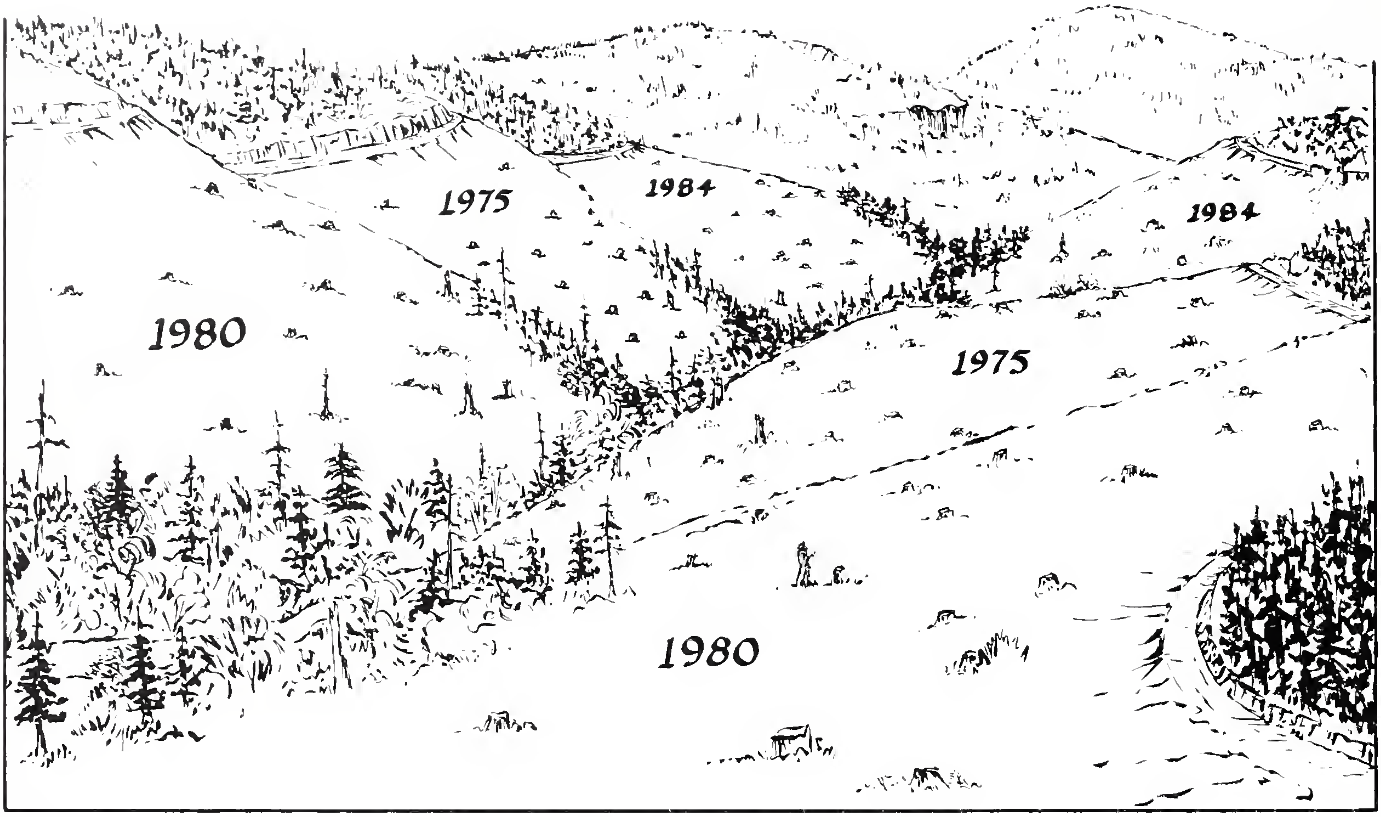


Figure 18.—Wildlife tree retention between harvest unit boundaries (modified from USDA 1982).

Figure 19.—Wildlife tree location (modified from USDA 1982, p. 8).

Partial and Intermediate Cuts (commercial thinning, salvage, shelterwood): The retention of snags can be more evenly distributed in partial-cut than in clearcut units because machinery and loggers can avoid working around trees specified for wildlife habitat (USDA 1982). Directional felling can be used to avoid hitting snags retained for wildlife.

Roads Washington and Oregon state laws require the felling of snags within 100-200 feet of roads or other areas of high public use or equipment operation. Manage for safe snags along roads only if there is no probability of them hitting the road (USDA 1982). Snags retained adjacent to and especially above roads are susceptible to unauthorized removal by wood cutters.

Herbicide Application Aerial application of herbicides varies throughout the Pacific Northwest. Select snag and cull tree heights and locations to avoid conflicts with helicopter operations.

Slash burning Standing trees left for wildlife that survive logging operations may not survive slash burning operations in clearcuts. Snag types D and E are most susceptible to fire because they have lost moisture over the years. Snag types A through C generally have higher moisture content and do not burn easily. Snags may be protected by building firelines around them and in some cases placing fire retardant on the snags before slash burning. Hand and machine piling of slash is costly but is a reasonable approach to protect snag habitat retained for wildlife. The areas around the "protected" wildlife trees may be preburned before the total unit is ignited. Live trees that are damaged or killed during slash or prescribed fires should be left for wildlife trees, although such trees cannot be planned for.

A three-zone approach is recommended for retaining snags in units to be slash burned (U.S. Department of the Interior 1981) (fig. 21). Trees left in the interior of clearcut units have the least chance of spreading fire to adjacent forest (USDA 1982).

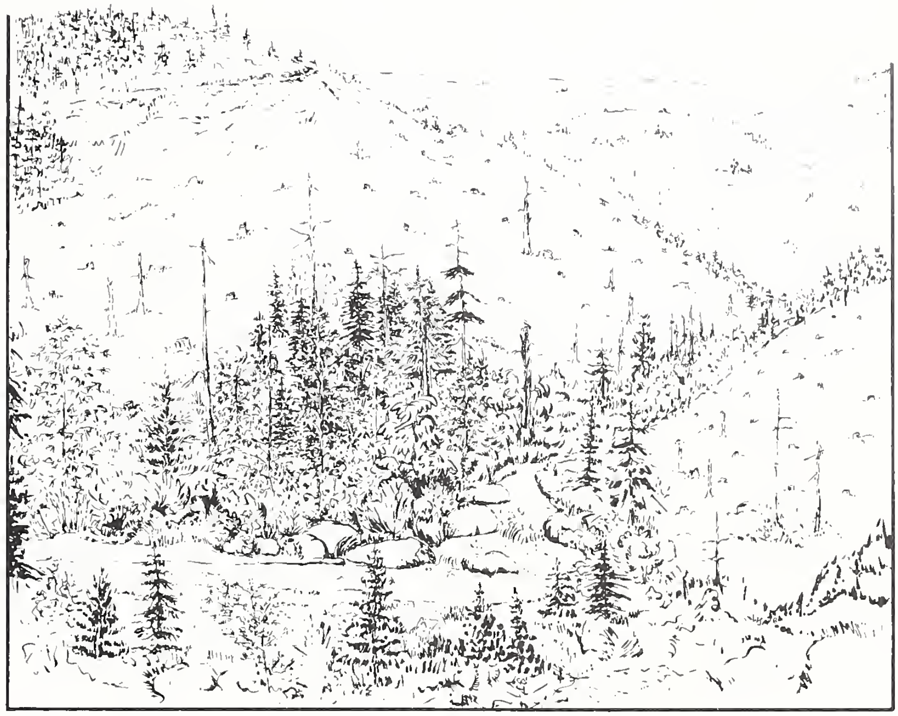


Figure 20.—Wildlife tree location in clearcut (modified from USDA 1982).

Snag-Free Corridors (firebreaks): Historically, snag-free corridors were required 200 feet outside harvest unit boundaries. Because of wildlife habitat values, only consider this practice in areas of extreme fire hazard.

Noncommercial Forest Land (wetland, oak woodland, grassland, bogs, meadows and others): Manage for 100 percent population level of cavity dwellers on all noncommercial forest land. Snags adjacent to the above habitats are components of the edge between habitat types (fig. 22).

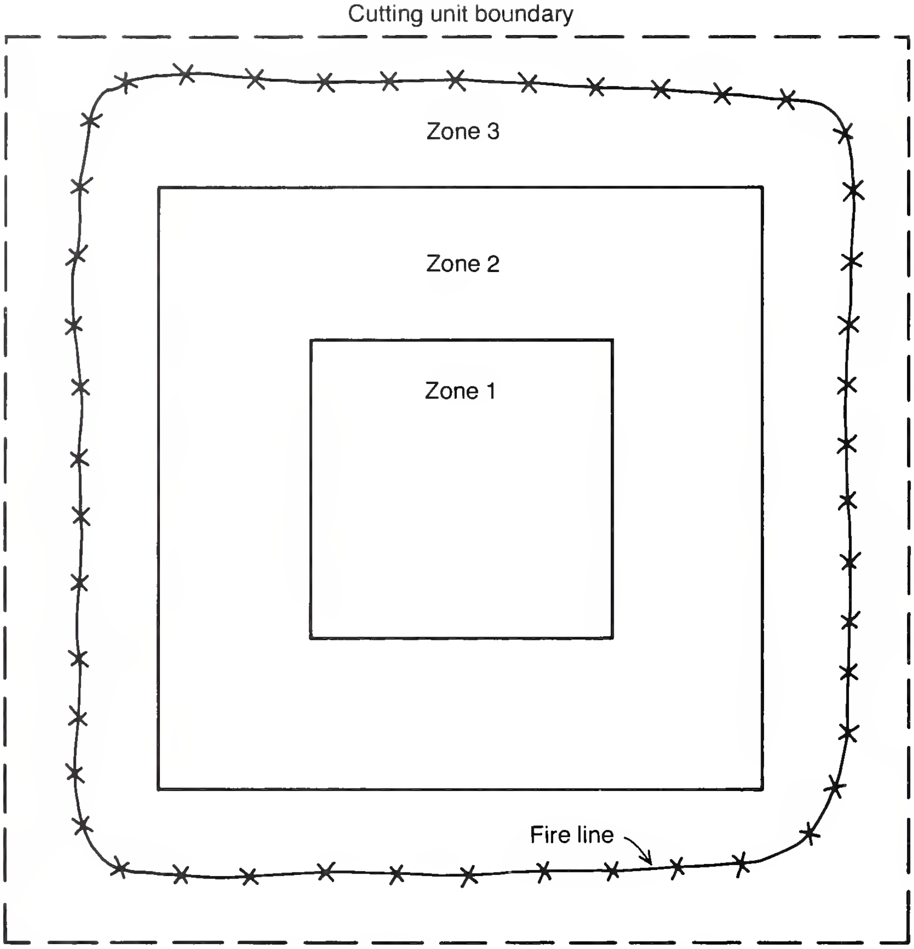
Commercial Forest Land-Withdrawn (riparian, fragile sites, bald eagle habitat, old-growth management areas, and others): Whenever possible, manage for the 100 percent population level of cavity dwellers on all withdrawn lands. Mortality salvage should only be considered in the case of a catastrophic event.

Snag Locations for Various Logging Systems

Landings

1. Standing-dead and live-defective trees may be left around landings if they are:
   a. outside the guyline circle;
   b. windfirm and not likely to blow over onto guylines, skylines or into the landing; and
   c. away from landing cut banks and leaning away from the landing and rigging.
2. Any standing-dead or live-defective tree which may fall, slide, or roll into a landing must be felled prior to setting up machinery.

3. Any standing-dead or live-defective tree that could fall on guylines or skylines must be felled prior to setting up machinery.



Location	Types of Wildlife Tree	Reason
Zone-1	Best for tall snags, soft or hard	Long distance from fireline
Zone-2	Best for short soft and hard snags	Reduced danger of spot fires
Zone-3	Best for hard or green snags	Green trees don't start spot fires

Figure 21.—Wildlife tree retention zones in clearcut units scheduled for slash burning (modified from U.S. Department of the Interior 1981).

Tractor Logging

Skid trails must be located away from a standing-dead tree a distance of at least ⅓ the height of the tree and opposite the directional lean of the tree.

Highlead Logging (Clearcut)

Snag types A and B may be left around landings outside the guyline circle if there is no chance of the trees blowing over or falling onto the landing or guylines. Type E snags may be left if they are outside the guyline circle and lean away from the landing, rigging, and work area. Snag types A through E may be left around the perimeter of the logging area if they are windfirm and vertical or lean away from the work area (fig. 23).

Skyline Logging – Non-Slackpulling Carriages (Clearcut)

Snags around the perimeter of the logging area must meet the same criteria as for highlead logging. Snag types A through E may be left in stream riparian zones providing they will not fall on the raised skyline or into work areas. Tall trees can be topped and left as snags (fig. 24).

Figure 22.—All wildlife trees on lands classified non-commercial forest should be retained.

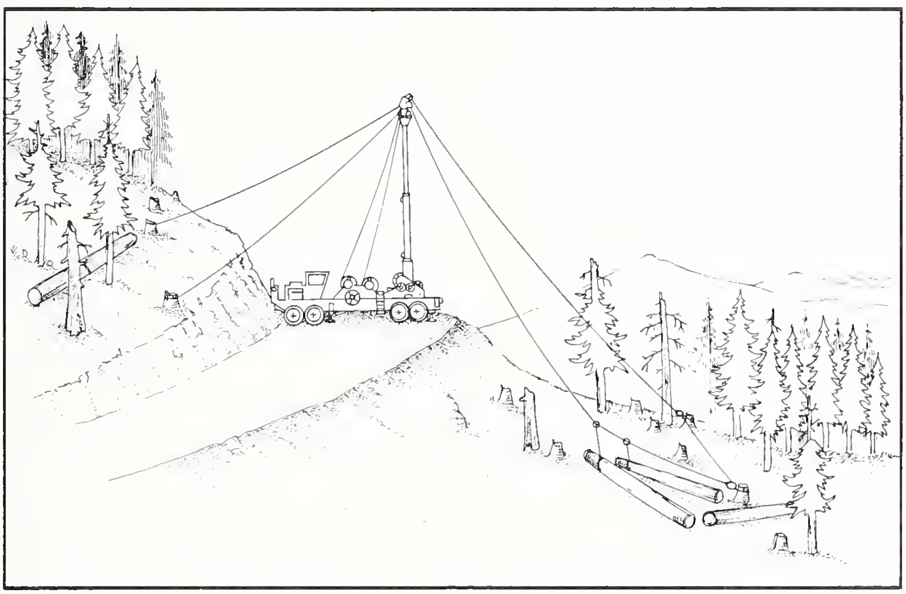


Figure 23.—Highlead logging (clearcut).

Skyline Logging – Slackpulling Carriage (Clearcuts)

Snags around the perimeter of the logging area must meet the same criteria as for highlead logging. Snags in buffer strips must meet the same criteria as for skylines with non-slackpulling carriages. Snag types A and B may be left between skyline corridors when there is no chance of them blowing over, falling on the skyline, or being hit by moving lines. Snag types D and E may be left between corridors if they are less than 20 feet in height, are stable, and won't be hit by moving lines (figs. 25 and 26). Rigging time will increase when snags are left between corridors because lines can't be "flopped" over to the next corridor.

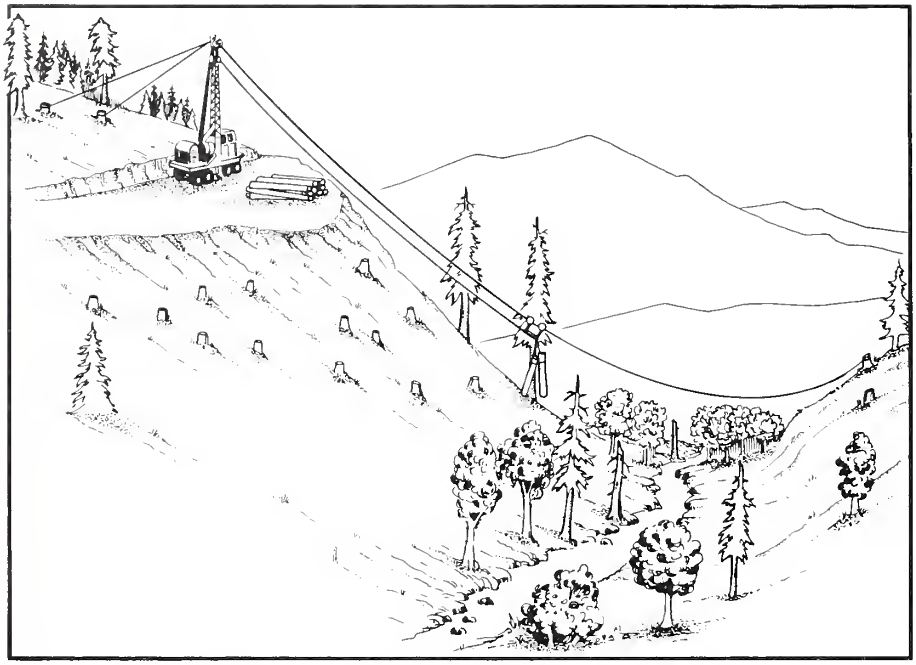


Figure 24.—Skyline logging - non-slackpulling carriage (clearcut).

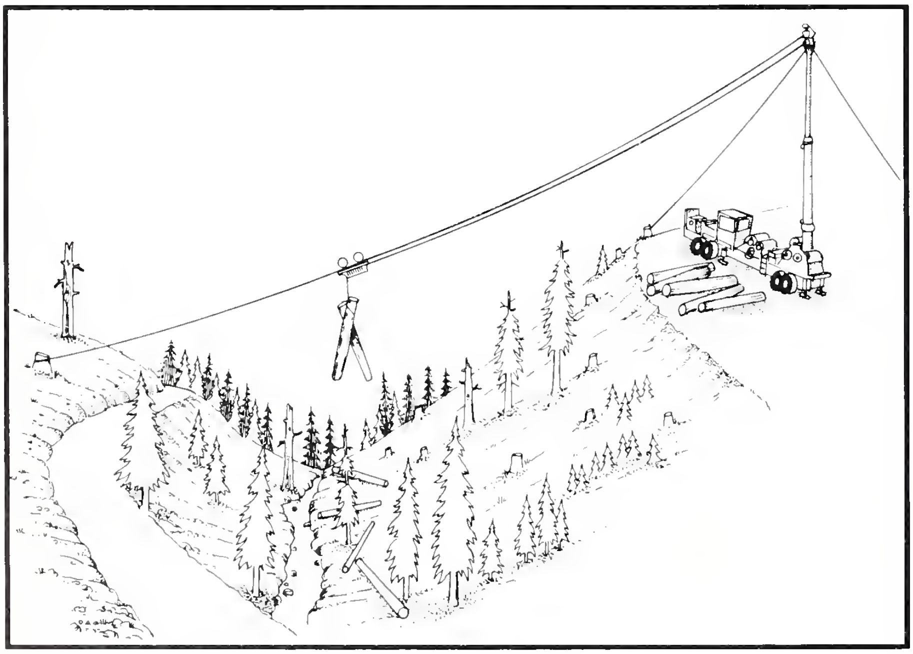


Figure 25.—Skyline logging - slackpulling carriage (clearcut).

Skyline Logging – Slackpulling Carriages (Partial Cuts)

Snags around the perimeter of the logging area must meet the same criteria as for highlead logging. Lateral yarding can be used successfully to avoid damage to reserved trees and snags. Snag types A through C can be left interspersed with leave trees if the snags are stable and have broken tops or sound tops that won't break out easily. Snag types D and E may be left between corridors if they are stable, with sound limbs, and less than 60 feet tall. All snags must be in a location where they will not be hit by moving lines (fig. 27).

Helicopter Logging

Snags with questionable stability, tops, or limbs should not be selected in areas where rotor downwash will occur when workers are present. Snags that could reach a landing or service pad must be felled prior to commencement of yarding operations.

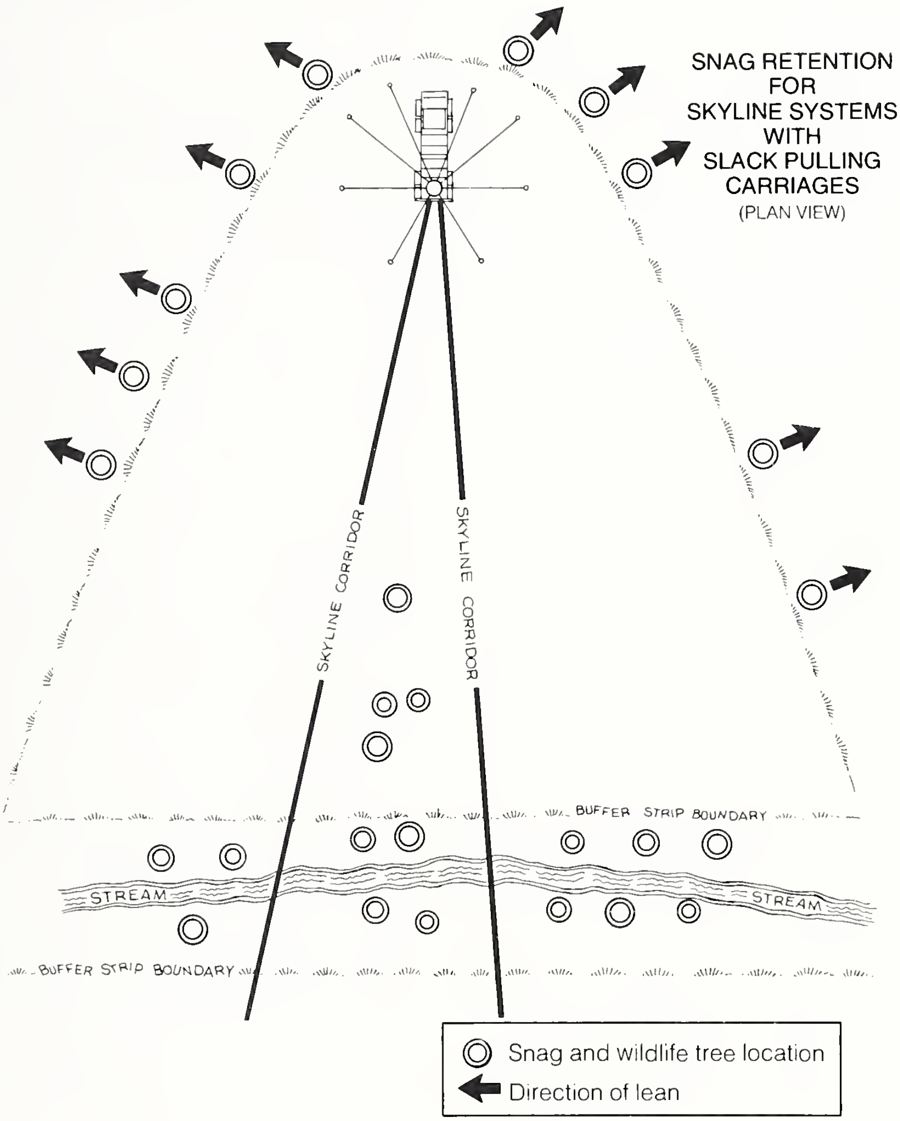


Figure 26.—Skyline logging - slackpulling carriage (clearcut).

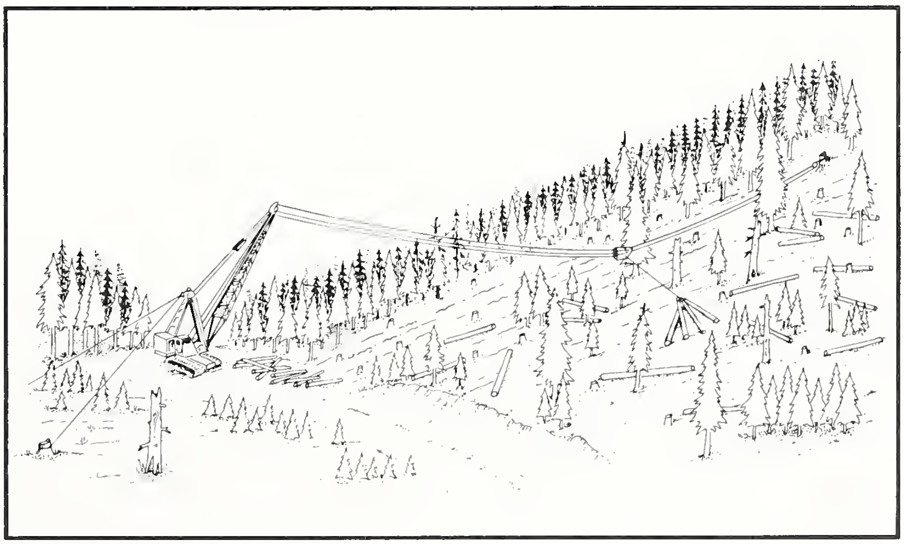


Figure 27.—Skyline logging - slackpulling carriage (partial cuts).

Artificial Nest Boxes

Intensive forest management practices in the Pacific Northwest have the potential of causing widespread population declines of cavity-dependent wildlife because of the limited provision of natural cavities. Snags are essential to the maintenance of populations of some forest birds since many of these species do not respond to nest boxes (McComb and Noble 1981b).

In most cases artificial nest boxes can only provide temporary habitat, on a small scale, where snags and cavities are limited. Aggressive nest box programs in some regions of the United States, however, have been credited with the recovery of two secondary cavity nesters (wood duck and bluebird)(Carey and Sanderson 1981, Gary and Morris 1980, Hurst 1983, Pinkowski 1979, Tate 1981).

Maser et al. (1981a) reported that natural cavities are superior to nest boxes. Natural cavities may have more favorable microclimates for cavity nesting, roosting and denning than artificial nest boxes, but results of studies to date are inconclusive (McComb and Noble 1981a, Van Camp and Henny 1975).

Several innovative ideas are being tested in an attempt to provide artificial cavities where natural ones are limited: 1) routing of artificial cavities (Carey and Gill 1983, Carey and Sanderson 1981); 2) cavity construction in live trees (Gano and Mosher 1983); and 3) polystyrene cylinders (Carey and Gill 1983, Grubb et al. 1983, Peterson and Grubb 1983).

Nest boxes and other artificial nest structures are generally too costly to install and maintain on a widespread basis, and in most cases cannot be substituted for snags (Froke 1983, McComb and Noble 1981b, Miller and Miller 1980, Thomas et al. 1979). Nest boxes and other artificially created cavities would accommodate only some secondary cavity-using species; excavators do not use nest boxes. Over the long term, land managers may find that providing snags designed to maintain insectivorous bird populations is a practical approach to providing biological control of many forest insect pests.

Economic Role of Snags and Cavity-Using Wildlife

It has only been in recent years that the importance of snags in forest management has received the attention of many forest land managers. For many years snags were looked at simply as a hazard or a hindrance to logging operations or as material to be salvaged for what sound wood fiber they might contain. Yet the average cull salvage value has been only about $0.50/1000 bd. ft., 1983 dollars.

Forests in the Pacific Northwest and throughout the United States annually suffer tremendous economic losses from insects. One role of insectivorous birds, including woodpeckers, in the forest ecosystem is insect predation (Wiens 1975). The role these birds play in regulating destructive forest insects has been reviewed by many authors (Anderson 1979, Bruns 1960, DeGraaf 1978a, Mannan 1977, Takekawa et al. 1982, Thomas et al. 1975, Wiens 1975). Evidence suggests that birds can reduce insect populations at endemic levels but cannot influence insect populations at epidemic levels.

Biological control of forest insects by insectivorous birds and bats, particularly year-round residents, has a positive and long-lasting effect. In comparison, the use of pesticides results in a temporary setback of insect populations with no regulation of future insect outbreaks. Also, insecticide control programs cost more and their effective period is shorter than biological control methods (Takekawa et al. 1982).

Some species of insectivorous birds are major predators on forest insect pests throughout the year. These include woodpeckers, nuthatches, creepers, chickadees, and wrens. Because these are resident species they are feeding on forest insects 5 to 6 months longer than migrant species such as foliage-gleaning warblers and flycatchers. The implication is that resident species are more valuable as biological control agents because they do not migrate but forage on insects throughout the year. Also, insect populations may be more prone to control when they are at their lowest population levels in the over-winter stage (M. Raphael, pers. comm.).

Several species of tree roosting bats forage nocturnally on forest insects while the diurnal insectivorous birds are roosting. The combined foraging activities of these animals provide continuous round-the-clock predation on insects.

The forest land manager should recognize that snags have important economic values other than just the wood fiber that can be salvaged, and that these values may more than compensate for problems created in the retention of snags. Although the complete ecological and economic role of snags may not be fully understood at this time, extreme care should be exercised in applying present management activities to ensure that future management options are not lost.

Management Considerations

Land managers have three options in the management of cavity-dependent wildlife: (1) provide no snags; (2) leave snags; or (3) construct artificial nest boxes for some of the secondary (nonexcavating) cavity-using species (Bull et al. 1980). Each option has been discussed in this chapter.

Snag management has two main components: quality and quantity of selected snags and future snags. The quality or usability of snags is as important as providing adequate numbers (Miller 1981). "Learning to manage dead wood as cleverly as the live tree will require creativity on the part of silviculturists and biologists" (Franklin 1982). Compromises need to be made between maximum wood yield and optimum wildlife habitat (Leopold 1978).

- Leave all hard snags, damaged and dying trees, and defective (cull) live trees during logging operations, except those considered safety hazards. Hard snags or cull trees should be left for recruitment of future soft snags (Evans 1978, Morrison and Meslow 1983; Raphael and White 1976, 1984; Scott 1979);
- If a tradeoff must be made, retain hard snags in favor of soft snags, large diameter (over 15 inches d.b.h.) snags in favor of small diameter snags, tall (over 60 feet) snags in favor of short snags, and snags with greater bark cover in favor of snags with little bark cover;
- Select snags and defective (cull) trees for retention that meet or exceed the minimum size requirements for nesting. Place emphasis on larger diameter trees because the larger trees remain standing longer, retain bark longer, and support a larger variety of wildlife (Conner 1979b, Evans and Conner 1979);
- Maintain, throughout the intensively managed forest, large snags or defective (cull) trees (15 - 24 inches d.b.h. or greater) at various stages of deterioration to supply cavity-user needs in succeeding forest rotations (Bull 1975);
- Maintain and manage variable size patches (50-300 acres) of mature and old-growth forest (100-400 years old) through extended rotations. These tracts should be well distributed throughout the managed forest to maintain maximum bird diversity (Bull 1975, Evans and Conner 1979, Franklin et al. 1981; McClelland 1979);
- Select islands or groups of live trees or snags in clearcut units to protect wildlife nesting, foraging, and food storage habitat (Evans and Conner 1979, Raphael and White 1976, Vahle and Patton 1983). Manage for one clump of 15 closely spaced snags over 9 inches d.b.h. on every five acres (Raphael and White 1984);
- Consider leaving high tree stumps for those species such as white-headed woodpeckers that will use short snags. These also support carpenter ant colonies and provide feeding sites for woodpeckers (McClelland 1979, 1980, Morrison et al. 1983, Otvos 1979, Raphael and White 1976);
- Retain live trees infected with heart rot and/or broken tops to accelerate snag production in managed stands (Conner 1979a, Scott et al. 1978);
- Maintain patches of hardwood and conifers 200-300 feet wide along riparian zones. These linear strips can be managed for cavity nesters while serving as corridors between old-growth management areas (Dickson et al. 1983, Evans and Conner 1979, McClelland 1979, Morrison 1982, Morrison and Meslow 1983);
- Consider closing roads to fuel woodcutters (see chapters 9, 10, and 11 for other benefits of road closures). In areas open to woodcutting restrict woodcutters to down materials or snags less than 8 inches d.b.h.;
- Emphasize snag retention downslope from road systems to protect snags from firewood cutting;
- Leave undisturbed all hardwoods having natural cavities or cavities excavated by wookpeckers (Marcot and Hill 1980);
- When burning slash, utilize protective measures (firetrails, machine piling, or fire retardant) where necessary to retain snags selected for wildlife habitat;
- Consider girdling some defective (cull) trees 12 inches d.b.h. or larger to provide future cavity sites and to increase woodpecker food supplies (DeGraaf 1978b); and
- Land managers should establish a monitoring program to evaluate whether management objectives for cavity-using wildlife species are being met.

References Cited

Akers, E. Mature Douglas-fir forest. Am. Birds. 29:1128; 1975.

Anderson, S. H. The avifaunal composition of Oregon white oak stands. Condor. 72:417-423; 1970.

Anderson, S. H. Seasonal variations in forest birds of western Oregon. Northw. Sci. 46:194-206; 1972.

Anderson, S. H. Concluding remarks. In: Dickson, J. G.; Conner, R. N.; Fleet, R. R. [and other] eds. The role of insectivorous birds in forest ecosystems: Proceedings of a symposium; 1978 July 13-14; Nacogdoches, TX. New York: Academic Press, Inc.: 1979: 375-381.

Balda, R. P. The relationship of secondary cavity nesters to snag densities in western conifer forests. Wildl. Hab. Bull. 1. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Region: 1975. 37 p.

Balgooyen, T. G. Behavior and ecology of the American kestrel (Falco sparverius.) in the Sierra Nevada of California. Univ. Calif. Pub. Zool., V. 103. Berkeley, CA: University of California Press; 1976. 83 p.

Beaver, D. L. Avian species diversity and habitat use in forests of the Sierra Nevada, California. Berkeley, CA: University of California; 1972. 206 p. Thesis.

Beebe, S. B. Relationships between insectivorous hole-nesting birds and forest management. New Haven, CT. Yale University, School of Forestry and Environmental Studies. Multilithed. 1974. 49 p.

Bent, A. C. Life histories of North American woodpeckers. New York. Dover Publ.: 1964. 334 p. (reprint of 1939 ed.).

Beuter, J. H.; Johnson, K. N.; Scheurman, H. L. Timber for Oregon's tomorrow: an analysis of reasonably possible occurences. Res. Bull. No. 19. Corvallis, OR: Oregon State University, School of Forestry, For. Research Lab.; 1976. 111 p.

Bock, C. E., Raphael, M.; Bock, J. H. Changing avian community structure during early post-fire succession in the Sierra Nevada. Wils. Bull. 89:119-123; 1978.

Bruns, H. The economic importance of birds in forests. Bird Study. 7 (4): 193-208; 1960.

Bull, E. L. Habitat utilization of the pileated woodpecker, Blue Mountains, Oregon. Corvallis, OR: Oregon State University; 1975. 58 p. Thesis.

Bull, E. L. Specialized habitat requirement of birds: snag management, old growth, and riparian habitat. In: DeGraaf, R. M., ed. Proceedings of the workshop on nongame bird habitat management in the coniferous forests of the western United States. 1977 February 7-9; Portland, OR. Gen. Tech. Rep. PNW-64. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1978: 74-82.

Bull, E. L.; Meslow, E. C. Habitat requirements of the pileated woodpecker in northeastern Oregon. J. For. 75(6): 335-337; 1977.

Bull, E. L.; Partridge, A. D.; Williams, W. G. Creating snags with explosives. Res. Note PNW-393, U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 4 p.

Bull, E. L.; Twombly, A. D.; Quigley, T. M. Perpetuating snags in managed mixed conifer forest of the Blue Mountains, Oregon. In: DeGraaf, R. M., tech, coord. Proceedings of the workshop on management of western forests and grasslands for nongame birds. 1980 February 11-14; Salt Lake City, UT. Gen. Tech. Rep. INT-86. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980: 325-336.

Carey, A. B. and Gill, J. D. Direct habitat improvements — some recent advances. In: Davis, J. W.; Goodwin G. A.; and Ockenfels, R. A. eds. Snag Habitat Management, Proceedings of the symposium. 1983 June 7-9; Flagstaff, AZ. Gen. Tech. Rep. RM-99. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1983: 80-87.

Carey, A. B.; Sanderson, H. R. Routing to accelerate tree-cavity formation. Wildl. Soc. Bull. 9(1): 14-21; 1981.

Cline, S. P. The characteristics and dynamics of snags in Douglas-fir forests of the Oregon Coast Range. Corvallis, OR: Oregon State University; 1977. 106 p. Thesis.

Cline, S. P.; Berg, A. B.; Wight, H. M. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. J. Wildl. Manage. 44(4): 773-786; 1980.

Conner, R. N. Snag managment for cavity nesting birds. In: DeGraaf, R. M., ed. Proceedings of the workshop on managment of southern forests for nongame birds. 1978 January 24-26; Atlanta, GA. Gen. Tech. Rep. SE-14. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeast Forest Experiment Station; 1978: 120-128.

Conner, R. N. Seasonal changes in woodpecker foraging methods: strategies for winter survival. In: Dickson, J. G.; Conner, R. N.; Fleet, R. R.; [and others], eds. The role of insectivorous birds in forest ecosystems: Proceedings of a symposium. 1978 13-14; Nacogdoches, TX. New York: Academic Press, Inc.; 1979a: 95-105.

Conner, R. N. Minimum standards and forest wildlife managment, Wildl. Soc. Bull. 7(4): 293-296; 1979b.

Conner, R. N.; Dickson, J. G.; Locke, B. A. Herbicide-killed trees infected by fungi: potential cavity sites for woodpeckers. Wildl. Soc. Bull. 9(4): 308-310; 1981.

Conner, R. N.; Dickson, J. G.; Williamson, J. H. Potential woodpecker nest trees through artificial innoculation of heart rots. In: Davis, J. W.; Goodwin, G. A.; and Ockenfels, R. A. eds. Snag habitat management: Proceedings of the symposium. 1983 June 7-9; Flagstaff, AZ. Gen. Tech. Rep. RM-99. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1983: 68-72.

Conner, R. N.; Hooper, R. G.; Crawford, H. S.; Mosby, H. S. Woodpecker nesting habitat in cut and uncut woodlands in Virginia. J. Wildl. Manage. 39 (1): 144-150; 1975.

Conner, R. N.; Miller, Jr., O. K.; Adkisson, C. S. Woodpecker dependence on trees infected by fungal heart rots. Wilson Bull. 88(4): 575-581; 1976.

Curtis, R. O.; Clendenen, G. W.; Ruekema, D. L.; DeMars, D. J. Yield tables for managed stands of coast Douglas-fir. Gen. Tech. Rep. PNW-135. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1982. 182 p.

DeGraaf, R. M. The importance of birds in ecosystems. In: DeGraaf, R. M., ed. Proceedings of the workshop on nongame bird habitat management in the coniferous forests of the western United States. 1977 February 7-9; Portland, OR. Gen. Tech. Rep. PNW-64. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1978a: 5-11.

DeGraaf, R. M. New life from dead trees. Natl. Wildl. 16(4): 29-31; 1978b.

Dickson, J. G.; Conner, R. N.; Williamson, J. H. Snag retention increases bird use of a clear-cut. J. Wildl. Manage. 47(3): 799-804; 1983.

Dingledine, J. V. and Haufler, J. B. The effect of firewood removal on breeding bird populations in a northern oak forest. In: Davis, J. W.; Goodwin, G. A.; Ockenfels, R. A. eds. Snag habitat management; Proceedings of the symposium. 1983 June 7-9; Flagstaff, Az. Gen. Tech. Rep. RM-99. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1983: 45-50.

Edwards, R. Y. and Stirling, D. Disturbed Douglas-fir coast forest. Audubon Field Notes 16: 524; 1962.

Evans, K.E. Forest management opportunities for songbirds. 43rd North Am. Wildl. and Nat. Resour. Conf. Trans.; Washington, DC: Wildlife Management Institute; 1978: 68-77.

Evans, K. E.; Conner, R. N. Snag management. In: DeGraaf, R. M.; Evans, K. E. eds. Proceedings of the workshop on management of north central and northeastern forests for nongame birds. 1979 January 23-25; Minneapolis, MN. Gen. Tech. Rep. NC-51, St. Paul, MN.: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1979: 211-225.

Forsman, E. D. Habitat utilization by spotted owls in west-central Cascades of Oregon. Corvallis, OR: Oregon State University: 1980. 95 p. Dissertation.

Forsman, E. D.; Horn, K. M.; Neitro, W. A. Spotted owl research and management in the Pacific Northwest. 47th North Am. Wildl. and Nat. Resour. Conf. Trans.; Washington, DC: Wildlife Management Institute; 1982: 323-331.

Franklin, J. F. Old-growth forests in the Pacific Northwest, an ecological view. Proceedings of a conference: Old growth forests: A balanced perspective. 1982 February 12-14, Eugene, OR: University of Oregon, Bureau of Governmental Research and Service; 1982: 5-27.

Franklin, J. F.; Cromack, Jr., K.; Denison, W.; [and others]. Ecological characteristics of old-growth Douglas-fir forest. Gen. Tech. Rep. PNW-118. Portland, OR. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 48 p.

Froke, J. B. The role of nestboxes in bird research and management. In: Davis, J. W.; Goodwin, G. A.; Ockenfels, R. A. eds. Snag habitat management; Proceedings of the symposium. 1983 June 7-9; Flagstaff, AZ. Gen. Tech. Rep. RM-99. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1983: 10-13.

Gale, R. M. Snags, chainsaws and wildlife: one aspect of habitat management. Presentation to the 4th Annual Joint Conference American Fisheries Society and Wildlife Society, North Lake Tahoe, NV. 1973. In: Yoakum, J., ed. Cal-Neva Wildl. Trans. 1973: 97-112.

Gano, R. D. Jr., Mosher, J. A. Artificial cavity construction — an alternative to nest boxes. Wildl. Soc. Bull. 11(1): 74-76; 1983.

Gary, J. L.; Morris, M. J. Constructing wooden boxes for cavity-nesting birds. Res. Note RM-381. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980. 8 p.

Graham, R. L. L. Biomass dynamics of dead Douglas-fir and western hemlock boles in mid-elevation forests of the Cascade Range. Corvallis, OR: Oregon State University; 1981. 152 p. Dissertation.

Grinnell, J. and Storer, T. I. Animal life in the Yosemite. Berkeley, CA: Univ. California Press; 1924. 752 p.

Grubb, T. C., Jr.; Petit, D. R.; Krusac, D. L. Artificial trees for primary cavity users. In: Davis, J. W.; Goodwin, G. A.; Ockenfels, R. A. eds. Snag habitat management: Proceedings of the symposium. 1983 June 7-9; Flagstaff, AZ. Gen. Tech. Rep. RM-99. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1983: 151-154.

Gutiêrrez, R. J. and Koenig, K. D. Characteristics of storage trees used by acorn woodpeckers in two California woodlands. J. For. 76: 162-164; 1978.

Haapanen, A. Bird fauna of the Finnish forests in relation to forest succession. I. Ann. Zool. Fenn. 2: 153-196; 1965.

Hagar, D. C. The interrelationships of logging, birds, and timber regeneration in the Douglas-fir region of northwestern California. Ecology. 41(1): 116-125; 1960.

Harrison, C. A field guide to the nests, eggs and nestlings of North American birds. New York, NY: Collins; 1978, 416 p.

Horvath, O. Contributions to nesting ecology of forest birds. Vancouver, B.C.: University of British Columbia; 1963. 181 p. Thesis.

Hurst, G. A. Use of nesting boxes on young loblolly pine plantations. In: Davis, J. W.; Goodwin, G. A; Ockenfels, R. A. eds. Snag habitat management: Proceedings of the symposium. 1983 June 7-9; Flagstaff, AZ. Gen. Tech. Rep. RM-99. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1983: 155-158.

Jackman, S. M. Some characteristics of cavity nesters: Can we ever leave enough snags? Paper presented at the Oregon Chapter, The Wildlife Society, 1974 Jan. Corvallis, OR: Oregon State University, Oregon Cooperative Wildlife Research Unit; 1974a. 10 p.

Jackman, S. M. Woodpeckers of the Pacific Northwest; their characteristics and their role in the forest. Corvallis, OR; Oregon State University; 1974b. 147 p. Thesis.

Jackson, J. A. How to determine the status of a woodpecker nest. Living-Bird. 15: 205-219, 1976.

Jackson, J. A. Insectivorous birds and North American forest ecosystems. In: Dickson, J. G.; Conner, R. N.; Fleet, R. R.; [and others], eds. The Role of Insectivorous Birds in Forest Ecosystems: Proceedings of a symposium; 1978 July 13-14; Nacogdoches, TX. New York, NY: Academic Press, Inc.; 1979: 1-7.

Juday, G. P. Old-growth forest: a necessary element of multiple use and sustained yield national forest management. Environmental Law. 8(2): 497-522; 1978.

Kilgore, B. M. Response of breeding bird populations to habitat changes in a giant sequoia forest. Am. Midl. Nat. 85: 135-152; 1971.

Kilham, L. Reproductive behavior of yellow-bellied sapsuckers: 1. Preference for nesting in Fomes-infected aspens and nest hole interrelations with flying squirrels, raccoons, and other animals. Wilson Bull. 83(2): 159-171; 1971.

Kilham, L. Courtship and the pair-bond of pileated woodpeckers. Auk. 96: 587-594; 1979.

Kimmey, J. W.; Furniss, R. L. Deterioration of fire-killed Douglas-fir. Tech. Bull. 851. Washington, DC: U.S. Department of Agriculture, Forest Service; 1943. 61 p.

Knight, R. L. Oregon white oak forest. Amer. Birds. 33: 82; 1979.

Larson, T. A. Ecological correlates of avian community structure in mixed-conifer habitat: an experimental approach. Chicago, IL. Illinois State University; 1981. 92 p. Dissertation.

Leopold, A. S. Wildlife and forest practice. In: Brokaw, H. P., ed. Wildlife and America. Washington, DC. Council on Environmental Quality; 1978: 108-120.

Lint, J. Snag creation through topping of old-growth with explosives. Presentation at the Joint Annual Meeting of the Oregon Chapters of the American Fisheries Society and the Wildlife Society, Eugene, OR: 1981 January 28-30.

McClelland, B. R. Relationships between hole-nesting birds, forest snags, and decay in western larch — Douglas-fir forests of the northern Rocky Mountains. Missoula, MT: University of Montana; 1977. 498 p. Dissertation.

McClelland, B. R. The pileated woodpecker in forests of the northern Rocky Mountains. In: Dickson, J. G., Conner, R. N.; Fleet, R. R.; [and others], eds. The role of insectivorous birds in forest ecosystems. Proceedings of a symposium: 1978 July 13-14, Nacogdoches, TX. New York: Academic Press Inc.; 1979: 283-299.

McClelland, B. R. Influences of harvesting and residue management on cavity-nesting birds. In: Proceedings of the symposium on environmental consequences of timber harvesting in Rocky Mountain coniferous forests. Gen. Tech. Rep. INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980: 469-496.

McClelland, B. R.; Frissell, S. S. Identifying forest snags useful for hole-nesting birds. J. For. 73(12): 414-417; 1975.

McClelland, B. R.; Frissell, S. S., Fischer, W. C.; Halvorson, C. H. Habitat management for hole-nesting birds in forests of western larch and Douglas-fir. J. For. 77(8): 480-483; 1979.

McComb, W. C.; Noble, R. E. Microclimates of nest boxes and natural cavities in bottomland hardwoods. J. Wildl. Manage. 45(1): 284-289; 1981a.

McComb, W. C.; Noble, R. E. Nest-box and natural-cavity use in three mid-south forest habitats. J. Wildl. Manage. 45(1): 93-101; 1981b.

MacRoberts, M. H. and MacRoberts. B. R. Social organization and behavior of the acorn woodpecker in central coastal California. A.O.U. Ornith. Mono. 21. 1976. 115 p.

Mannan, R. W. Use of snags by birds, Douglas-fir region, western Oregon. Corvallis, OR. Oregon State University; 1977. 114 p. Thesis.

Mannan, R. W. Bird populations and vegetation characteristics in managed and old-growth forests, northeastern Oregon. Corvallis, OR: Oregon State University, 1982. 66 p. Dissertation.

Mannan, R. W.; Meslow, E. C.; Wight, H. M. Use of snags by birds in Douglas-fir forests, western Oregon. J. Wildl. Manage. 44(4): 787-797; 1980.

Manuwal, D. A.; Zarnowitz, J. Cavity nesting birds of the Olympic National Forest. Seattle, WA. University of Washington, College of Forest Resources; 1981, 144 p.

Marcot, B. G.; Hill, R., Flammulated owls in northwestern California. Western Birds. 11: 141-149; 1980.

Maser, C.; Anderson, R.; Bull, E. L. Aggregation and sex segregation in northern flying squirrels in northeastern Oregon, an observation. Murrlet. 62(2): 54-55; 1981a.

Maser, C.; Mate, B. R.; Franklin, J. F.; Dyrness, C. T. Natural history of Oregon Coast mammals. Gen. Tech. Rep. PNW-133. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981b. 496 p.

Meslow, E. C. The relationship of birds to habitat structure — plant communities and successional stages. In: DeGraaf, R. M., ed. Proceedings of the workshop on nongame bird habitat management in the coniferous forests of the western United States. 1977 February 7-9; Portland, OR. Gen. Tech. Rep. PNW-64. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1978: 12-18.

Miller, E. and Miller, D. R. Snag use by birds. In: DeGraaf, R. M., tech. coord. Proceedings of the workshop on management of western forests and grasslands for nongame birds; 1980 February 11-14; Salt Lake City, UT. Gen. Tech. Rep. INT-86, Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980: 337-356.

Miller, J. W. Snags needed for forest health. Journal of the Nation-wide Forest Planning Clearinghouse. 2(2): 1981.

Morrison, M. L. Response of avian communities to herbicide-induced vegetation changes, western Oregon. Corvallis, OR: Oregon State University; 1982. 77 p. Dissertation.

Morrison, M. L.; Meslow, E. C. Avifauna associated with early growth vegetation on clearcuts in the Oregon Coast ranges. Res. Pap. PNW-305. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1983. 12 p.

Morrison, M. L.; Morrison, S. W. Population trends of woodpeckers in the Pacific Coast Region of the United States. American Birds. 37(4): 361-363; 1983.

Morrison, M. L.; Raphael, M. G.; Heald, R. C. The use of high-cut stumps by cavity-nesting birds. In: Davis, J. W.; Goodwin, G. A.; Ockenfels, R. A. eds. Snag habitat management: Proceedings of the symposium. 1983 June 7-9; Flagstaff, AZ. Gen. Tech. Rep. RM-99, Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1983: 73-79.

Nice, M. M. Nesting success in altricial birds. Auk. 74: 305-321; 1957.

Otvos, I. S. The effects of insectivorous bird activities in forest ecosystems. In: Dickson, J. G.; Conner, R. N., Fleet, R. R., [and others], eds. The role of insectivorous birds in forest ecosystems: Proceedings of a symposium; 1978 July 13-14; Nacogdoches, TX. New York: Academic Press, Inc.; 1979: 341-374.

Peterson, A. W.; Grubb, Jr., T. C. Artificial trees as a cavity substrate for woodpeckers. J. Wildl. Manage. 47(3): 790-798; 1983.

Pinkowski, B. C. Foraging ecology and habitat utilization in the genus Sialia.. In: Dickson, J. C.; Conner, R. N.; Fleet, R. R.; [and others], eds. The role of insectivorous birds in forest ecosystems: Proceedings of a symposium; 1978 July 13-14; Nacogdoches, TX. New York: Academic Press, Inc.; 1979: 165-190.

Pugh, E. A. and Pugh, R. W. Humid coastal redwood forest. Audubon Field Notes. 11: 440-441; 1957.

Putnam, B. J. Songbird populations of precommercially thinned and unthinned stands of ponderosa pine in east-central Washington. Corvallis, OR: Oregon State University; 1983. 58 p. Thesis.

Raphael, M. G. Utilization of standing dead trees by breeding birds at Sagehen Creek, California. Berkeley, CA: University of California; 1980. 195 p. Dissertation.

Raphael, M. G. Cavity-nesting bird response to declining snags on a burned forest: a simulation model. In: Davis, J. W.; Goodwin, G. A.; Ockenfels, R. A. eds. Snag habitat management; Proceedings of the symposium. 1983 June 7-9, Flagstaff, AZ. Gen. Tech. Rep. RM-99. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1983: 211-215.

Raphael, M. G.; Brack, J. W.; LeValley, R. R.; Taylor, C. A. Administrative study of relationships between wildlife and old-growth forest stands, Phase III. Interim Rept. Suppl. RO-44 under Master Agreement No. 21-395. San Francisco, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region. 1981. 23 p.

Raphael, M. G.; White, M. Avian utilization of snags in a northern California coniferous forest (Phases 1 and 11), Berkeley, CA: University of California, Department of Forestry and Conservation; Presented to the U.S. Forest Service, Region 5, San Francisco, CA: 1976: 28 p.

Raphael, M. G. and White, M. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildl. Monogr. 86; 1984. 66 p.

Roth, L. F. Disease in young-growth stands of Douglas-fir and western hemlock. In: Berg, A. B., ed. Management of young-growth Douglas-fir and western hemlock. Corvallis, OR. Oregon State University, School of Forestry; 1970: 38-43.

Rushmore, F. M. Techniques for calling sapsuckers and finding their nesting territories. Upper Darby, PA. Res. Pap. NE-281. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station; 1973. 7 p.

Scott, V. E. Characteristics of ponderosa pine snags used by cavity-nesting birds in Arizona. J. For. 76(1): 26-28; 1978.

Scott, V. E. Bird responses to snag removal in ponderosa pine. J. For. 77(1): 26-28; 1979.

Scott, V. E.; Whelan, J. A.; and Alexander, R. R. Dead trees used by cavity-nesting birds on the Fraser Experimental Forest: A case history. Res. Note RM-360. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1978. 4 p.

Scott, V. E.; Whelan, J. A.; Svoboda, P. L. Cavity-nesting birds and forest management. In: DeGraaf, R. M., tech. coord. Proceedings of the workshop on management of western forests and grasslands for nongame birds. 1980 February 11-14; Salt Lake City, UT. Gen. Tech. Rep. INT-86. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980: 311-324.

Stallcup, P. L. Spatio-temporal relationships of nuthatches and woodpeckers in ponderosa pine forests of Colorado. Ecology. 49: 831-843; 1968.

Steinhart, P. Leave the dead. Audubon. 83(1): 6-7; 1981.

Swearingen, E. M. Group size, sex ratio, reproductive success and territory size in acorn woodpeckers. Western Birds. 8: 21-24; 1977.

Takekawa, J. Y.; Garton, E. O.; Langelier, L. A. Biological control of forest insect outbreaks: the use of avian predators. In: 47th North Am. Wildl. and Nat. Resour. Conf. Trans., Washington, DC: Wildlife Management Institute; 1982: 393-409.

Tanner, J. T. The ivory-billed woodpecker. Res. Rep. No. 1. New York: National Audubon Soc. 1942. 107 p.

Tate, J., Jr. The blue list for 1981 — The first decade. American Birds. 35 (1): 3-10; 1981.

Thomas, J. W.; Anderson, R. G.; Maser, C.; Bull, E. L.; Snags. Chapter 5. In: Thomas, J. W., tech. ed. Wildlife habitats in managed forests; the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979: 60-77.

Thomas, J. W.; Crouch, G. L.; Bumstead, R. S.; Bryant, L. D. Silvicultural options and habitat values in coniferous forests. In: Smith, D. R., tech coord. Proceedings of the symposium on management of forest and range habitats for nongame birds. 1975 May 6-9; Tucson, AZ. Gen. Tech. Rep. WO-1. Washington, DC: U.S. Department of Agriculture, Forest Service; 1975: 272-287.

USDA, Forest Service. Guidelines for selecting live or dead trees for wildlife habitat to meet logging safety standards. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1960. 15 p.

USDA, Forest Service. Spare that snag. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1980. 2 p.

USDA, Forest Service, Estacada Ranger Station. Wildlife tree management guidelines. Estacada, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Mt. Hood National Forest; 1982. 11 p.

U.S. Department of the Interior. Management of dead or defective trees, trial guidelines. Medford, OR: U.S. Department of the Interior, Bureau of Land Management, Medford District; 1981. 9 p.

Vahle, J. R.; Patton, D. R. Red squirrel cover requirements in Arizona mixed conifer forest. J. For. 81(1): 14-22; 1983.

VanCamp, L. F.; Henny, C. T. The screech owl: its life history and population ecology in northern Ohio. North American Fauna. Washington, DC. U.S. Department of the Interior, Fish and Wildlife Service; 1975. 65 p.

Verner, J. and Boss, A. S. eds. California wildlife and their habitats: western Sierra Nevada. Gen. Tech. Rep. PSW-37. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980. 439 p.

Von Haartman, L. The evaluation of resident versus migratory habits in birds: some considerations. Ornis Fenn. 45: 1-7; 1968.

Wellersdick, M. and Zalunardo, R. Characteristics of snags used by wildlife for nesting and feeding in the western Cascades, Oregon. Roseburg, OR: U.S. Department of Agriculture, Forest Service, Umpqua National Forest. 1978. 31 p.

White, M. and Raphael. M. Importance of wildlife to forest ecosystems. Berkely, CA: University of California, Department of Forestry and Conservation, Appendix B-5. In: Report for California State Board of Forestry. Prepared by study committee on snags. 1975: 17-21.

Wiens, J. A. Avian communities, energetics, and functions in coniferous forest habitats. In: Smith, D. R., tech. coord. Proceedings of the symposium on management of forest and range habitats for nongame birds. 1975 May 6-9; Tucson, AZ. Gen. Tech. Rep. WO-1. Washington, DC: U.S. Department of Agriculture, Forest Service; 1975: 226-265.

Wiens, J. A. Nongame bird communities in northwestern coniferous forests. In: DeGraaf, R.M., ed. Proceedings of the workshop on nongame bird habitat management in the coniferous forests of the western United States. 1977 February 7-9; Portland, OR. Gen. Tech. Rep. PNW-64. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1978: 19-31.

Wiens, J. A. and Nussbaum, R. A. Model estimation of energy flow in northwestern coniferous forest bird communities. Ecology 56: 547-561. 1975.

Zarn, M. Habitat management series for unique or endangered species — osprey *Pandion haliaetus carolinensis*. Tech. Note 254, Rep. 12. Denver, CO. U.S. Department of the Interior, Bureau of Land Management; 1974. 41 p.

Zarnowitz, J. E. and Manuwal, D. A. The effects of forest management on cavity-nesting birds in northwestern Washington. J. Wildl. Manage. 49(1): 255-263. 1985.

Zeedyk, W. D. and Evans, K. E. Silvicultural options and habitat values in deciduous forest. In: Smith, D. R., tech. coord. Proceedings of the symposium on management of forest and range habitats for nongame birds. 1975 May 6-9; Tucson, AZ. Gen. Tech. Rep. WO-1. Washington, DC: U.S. Department of Agriculture, Forest Service; 1975: 115-127.

8

Dead and Down Woody Material

Ronald Bartels
John D. Dell
Richard L. Knight
Gail Schaefer

Table of Contents

Introduction

Dead and down woody material in the form of stumps, root wads, bark, limbs, and logs, in various stages of decay, occurs in most forest ecosystems. This is especially true of the temperate and high temperate conifer forests west of the Cascade Range where highly productive forest sites are capable of producing large volumes of wood fiber. These dead and down materials have long been viewed as potential wood products that should be salvaged, as fuels that create fire hazards, as physical barriers to tree planting, and as a haven for small mammals which may impede forest regeneration. All of these are valid concerns; however, dead and down woody material serves many important functions that should be recognized. Not only is this material important in mineral cycling, nutrient mobilization, and natural forest regeneration, but it also creates a structure and diversity of habitats that are valuable to a great many wildlife species, terrestrial and aquatic.

Intensified forest management, responding to the ever-increasing demand for forest products, will have a strong influence on the amount and distribution of woody material that remains as wildlife habitat through present and future stand rotations. Leaving the perpetuation of large down material to chance will probably result in its disappearance from the managed forests of the future, along with the loss of dependent plant and wildlife species.

A thorough discussion of the ecological implications of slowly decomposing woody material in western forests was presented by Maser et al. (1979). The ecological principles and habitat relationships presented in that publication have broad application throughout western forests. A large part of the research used in developing those principles and relationships was conducted in forests west of the Cascades. Therefore, much of the information presented here has been adapted from Maser et al. (1979) and leans heavily on their work while exploring human influence on the disposition of dead and down woody materials during roading, timber harvest, reforestation, and fire management.

The Origin and Importance of Dead and Down Woody Material As Habitat for Wildlife

Origin of Dead and Down Woody Material

Natural tree mortality, which includes trees killed by insects, disease, or injury, provides snags to the forest environment. Snags eventually deteriorate, collapse, and become logs. Living trees that fall as a result of severe winds, landslides, and floods also are a source of logs. These logs, if not harvested, become the most significant element of the dead and down component of the forest.

Large snags and logs are integral components of old-growth stands. Both of these structural features are carried over into young stands that originate after wildfire or other natural catastrophe has removed the old-growth stand. Large snags and logs may or may not remain following timber harvest, but if planned for, both can be retained during forest management activities.

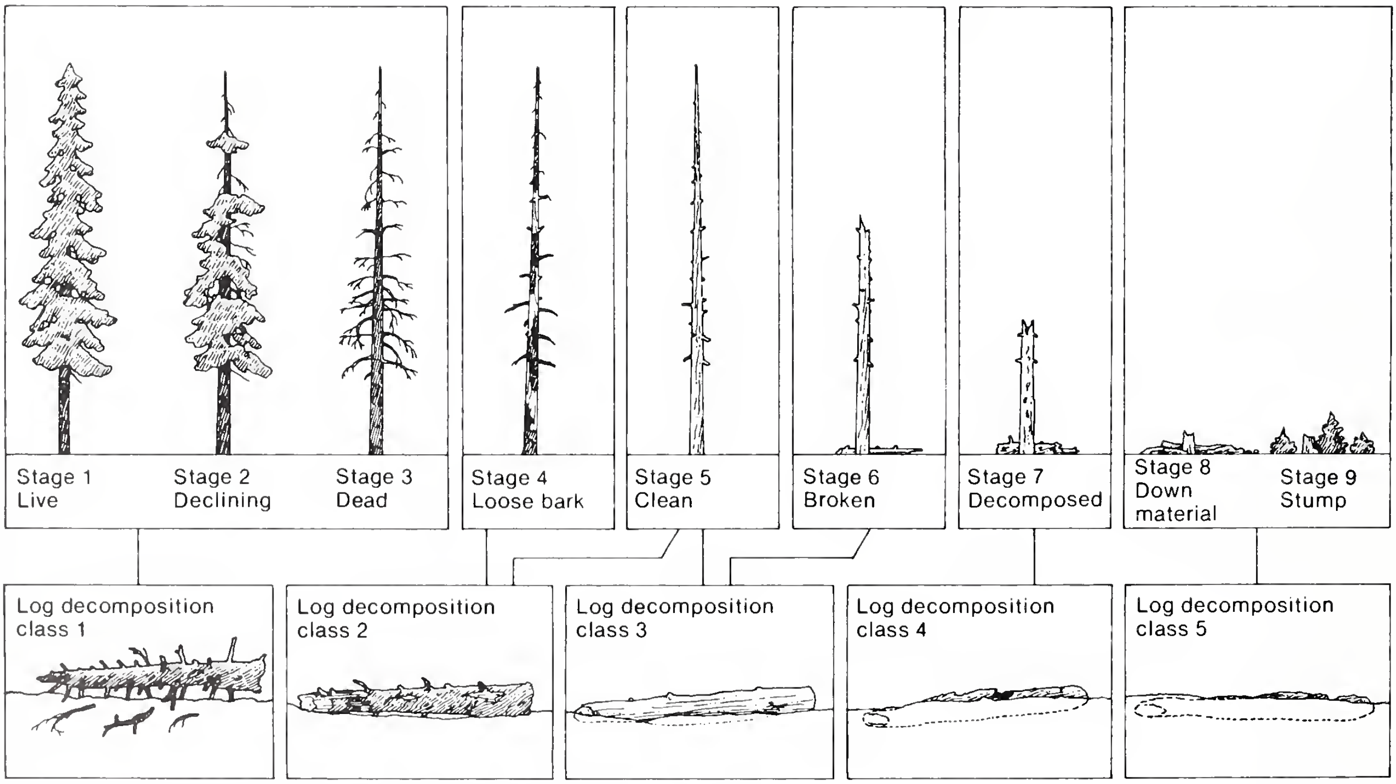


Figure 1.—When they fall, trees and snags immediately enter one of the first four log decomposition classes (reproduced from Maser et al. 1979, fig. 44, p. 80).

The starting point for a large down log is a large living tree which sometimes passes through the snag stage before falling. After trees fall, they go through recognizable stages of deterioration. One system for classifying the stages of log decay is a five-class scheme based on easily recognized physical characteristics (fig. 1 and table 1) (Maser et al. 1979; p. 80). When dead trees fall, they enter one of the first four log-decomposition classes, depending on their condition. For example, a live tree, felled as a result of a windstorm, becomes a decomposition-class 1 log, whereas the collapse of a deteriorating snag (Cline et al. 1980), creates either a decomposition-class 3 or 4 log (table 2).

Table 2—Snag condition translated into log decompostion class (reproduced from Maser et al. 1979, table 19, p. 80)

Snag stage	Snag condition	Log class
1-3	Hard snag	1
4-5	Hard snag	2
5-6	Soft snag	3
7	Soft snag, 70% + soft sapwood	4

The size, tree species, and condition of a log—along with moisture and temperature—determine the rate of decomposition. As a log decomposes, the plant community and life forms inhabiting it gradually change. These changes result from two processes—internal and external succession (fig. 2). Internal succession is related to the persistence of the log over time which normally is determined by the rate of decay. External succession is the change in the plant community surrounding the log.

Some species, such as alder and cottonwood, are very susceptible to decay and thus remain for a relatively short time. Conversely, some logs, such as fire-charred Douglas-fir, have persisted an estimated 470 years since fire destroyed the original stand (MacMillan et al. 1977). The length of time it takes a log of a given species and size to decompose is known as residence time.

Table 1—A 5-class system of log decomposition based upon work done on Douglas-fir (reproduced from Maser et al. 1979, Table 20, p. 80)

Log characteristics	Log decomposition class				
	1	2	3	4	5
Bark	intact	intact	trace	absent	absent
Twigs <3 cm (1.18 in)	present	absent	absent	absent	absent
Texture	intact	intact to partly soft	hard, large pieces	small, soft, blocky pieces	soft and powdery
Shape	round	round	round	round to oval	oval
Color of wood	original color	original color	original color to faded	light brown to faded brown or yellowish	faded to light yellow or gray
Portion of log on ground	log elevated on support points	log elevated on support points but sagging slightly	log is sagging near ground	all of log on ground	all of log on ground

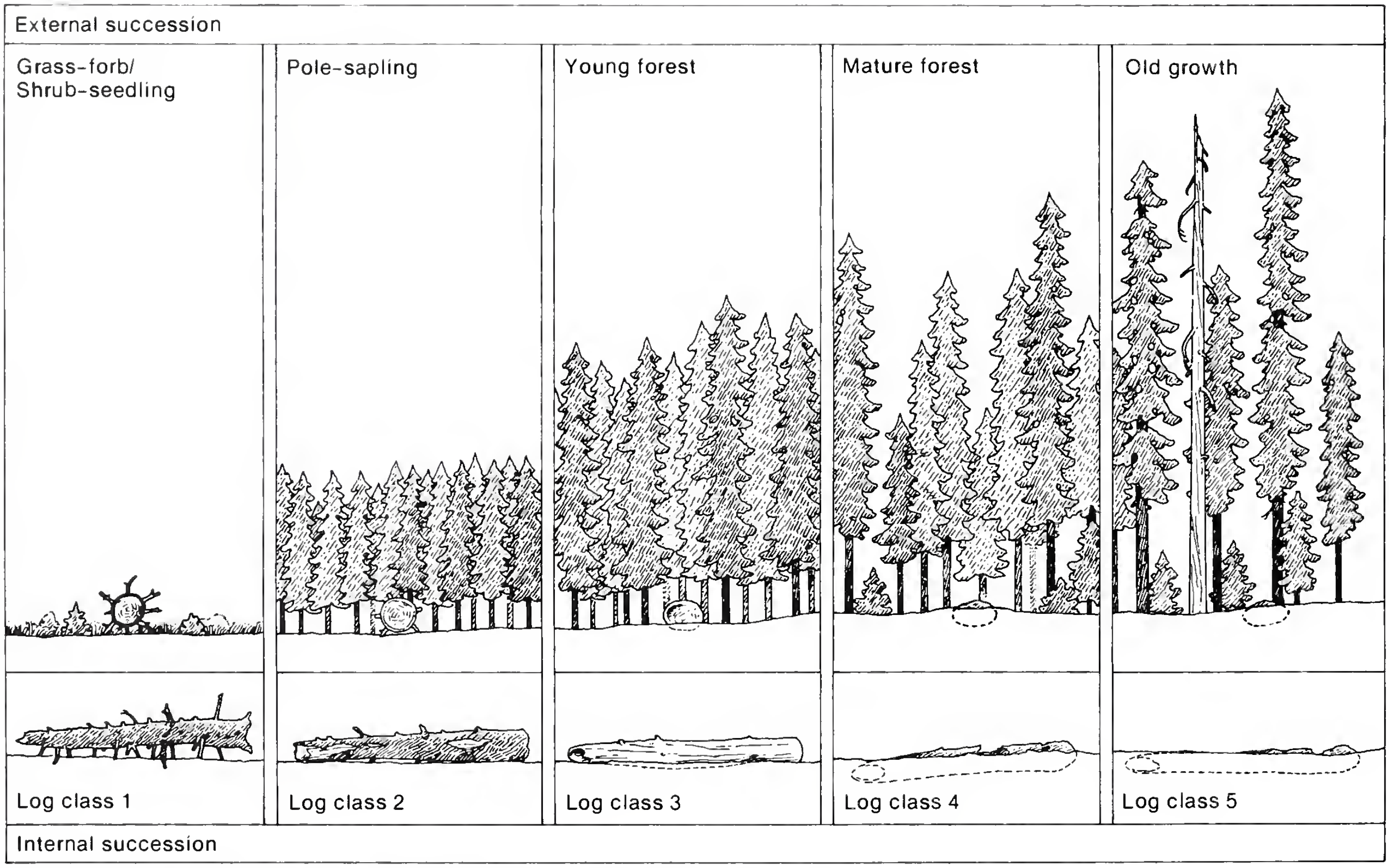


Figure 2.—Logs progress through two simultaneous successional processes—internal and external (reproduced from Maser et al. 1979, fig. 47, p. 83).

Figure 3.—Amphibians, such as the clouded salamander, require the protection that large moist logs provide.

As logs decompose they increase in moisture content and maintain a high moisture content throughout the process of decomposition. This is the basis for three ecosystem functions of down woody materials. First, many species of reptiles, amphibians, and small mammals require cool, moist microhabitats for some or all life history functions (Marcot 1979). Down logs provide suitable habitats for these functions (fig. 3). Second, logs serve as sites for nitrogen fixation by nonsymbiotic bacteria. Third, logs serve as favorable sites for regeneration of some species of tree seedlings (fig. 4).

Figure 4.—Logs serve as favorable sites for regeneration of some species of tree seedlings.

Habitat for Wildlife

Dead and down woody materials are important components of wildlife habitats in western forests. These materials furnish cover and serve as sites for feeding, reproducing, and resting for many wildlife species (Maser et al. 1979; and figs. 5 and 6). In forests west of the Cascade crest in Oregon and Washington, 150 terrestrial wildlife species are known to utilize dead and down woody materials as either a primary or a secondary component of their habitat requirements (appendix 8). Although many more species are casual users of this material, it is not considered an important enough element to be listed as a habitat requirement. Down logs and large woody debris are also an important component of aquatic habitats in forested areas (see chapter 10 and Swanson et al. 1976).

Appendix 20 shows how logs are used by wildlife species and which elements of dead and down woody material are most important for cover, feeding, reproducing, and resting. The size and decompostion stage of the material determine its usefulness to wildlife. In general, the larger the diameter and the greater the length of a log, the more useful it is; however, small material is better than none since even small logs will provide habitat for some wildlife species (Maser et al. 1979).

As a log approaches decomposition-class 3, (fig.1), the bark becomes loose and the space between it and the log provides hiding and thermal cover for wildlife (fig. 5). This condition persists through class 4. As the decomposition process continues through the class 4 and 5 stages, the log interior becomes soft enough for small mammals, such as the Pacific shrew, Trowbridge's shrew, and red-backed voles, to burrow inside. This opens the log interior to the introduction of mycorrhizal fungi. As decomposition progresses, the amount of small mammal activity alongside and within the log increases (Maser et al. 1979).

Other factors that influence wildlife use of dead and down woody material include the species compostion of the plant community, the successional stage of the surrounding stand, and the existing wildlife community (Maser et al. 1979). If new habitats are created, they must be within the dispersal distance of animals

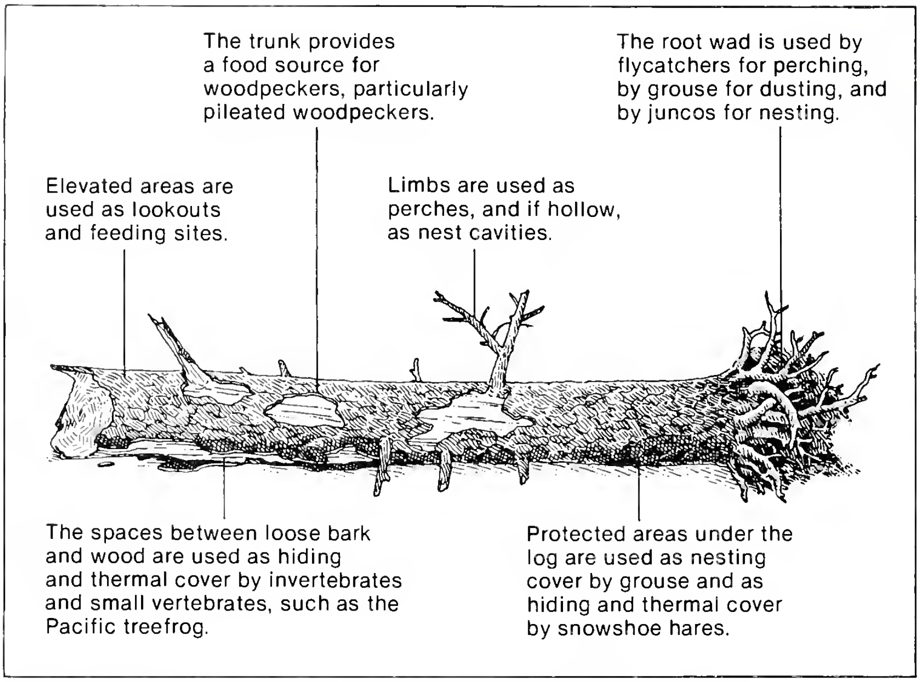


Figure 5.—A class 2 log showing some of the structural features important to wildlife (reproduced from Maser et al. 1979, fig. 42, p. 79).

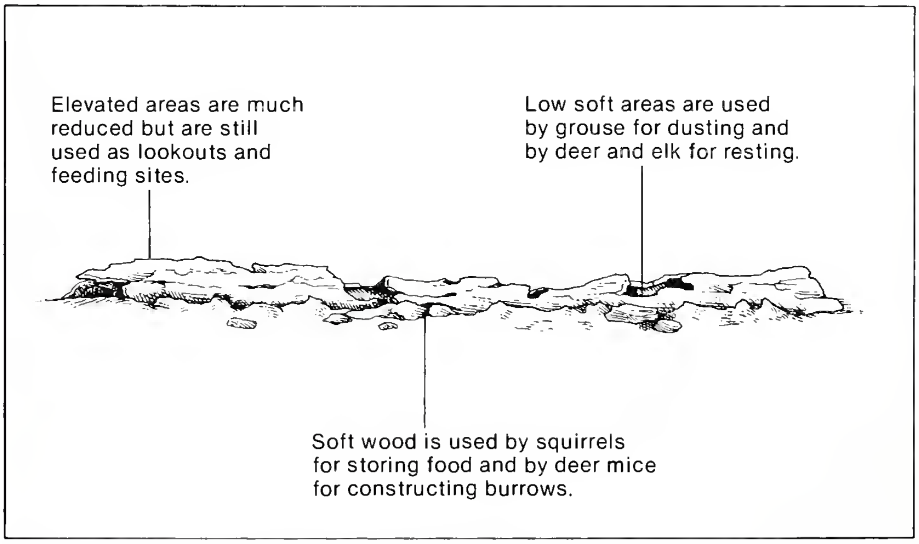


Figure 6.—A class 4 log showing advanced stage of decay and some of the structural features important to wildlife (reproduced from Maser et al. 1979, fig. 42, p. 79).

Figure 7.—Large logs provide cover during forest regeneration, enabling wildlife to use forage areas.

residing in adjacent stands if they are to be readily reoccupied (Jones & Stokes Associates, Inc. 1980). This is also true if forest activities are such that existing wildlife species are eliminated prior to the creation of new habitats.

The persistence of large logs has special importance in providing wildlife with habitat continuity over long periods of time and through major disturbances (Franklin et al. 1981). Logs may contribute significantly to re-establishment of animal populations by providing pathways along which small mammals, such as red-backed voles and chipmunks, can venture into clearcuts and other forest openings. Large logs or scattered piles of debris can be important as cover on a site during early stages of succession, enabling wildlife to use forage areas (fig. 7).

Forest management practices, such as prescribed burning, scarification, yarding of unmerchantable materials, and herbicide treatments, create significant changes in habitat for wildlife. The impact of these changes can be reduced if suitable down material is maintained on a site through stand rotations.

Nutrient Cycling

Dead and down woody material and the wildlife that inhabit this material play an important role in the cycling of nutrients within the forest ecosystem. Large proportions of some nutrients in the forest are contained in trees and leaf litter. This is especially true for phosphorous and nitrogen and to a lesser extent for various other mineral elements. Large amounts of nutrients are stored in branches, twigs, and foliage; smaller amounts are in the main trunk (Zinke et al. 1979).

Lichens in the canopy of old-growth forests fix significant amounts of nitrogen that ultimately become available to the entire forest through leaching, litter fall, and decomposition. Franklin et al. (1981) reported that significant epiphytic nitrogen inputs are mainly confined to old-growth stands.

Logs serve as storage compartments for energy and nutrients and as sites for nitrogen fixation. Logs may also provide physical stability, protecting a site from the loss of nutrients through surface erosion.

The discovery of significant bacterial nitrogen fixation in coarse woody debris is recent. Roskoski (1977) reported that greater decay and higher moisture contents were associated with a higher incidence of nitrogen fixation in woody debris. Franklin et al. (1981) reported that larger woody debris was probably more favorable for nitrogen fixation because large pieces create better moisture conditions and last longer, thereby providing a greater opportunity for inoculation by suitable bacteria. These important nutrients can then be made available to trees through association with mycorrhizal fungi that also find suitable growing conditions in large decomposing logs.

Mycorrhiza means "fungus-root" and is a symbiotic association of certain fungi with the roots of most vascular plants. Ectomycorrhiza is a type of root-fungus association necessary for survival of several families of trees including the pines, hemlocks, spruces, true firs, Douglas-fir, oaks, and alders (Maser et al. 1979).

In recent years, the role of mycorrhiza in plant nutrition has been widely recognized (Maser et al. 1978b). The fungi penetrate tiny, nonwoody rootlets of host plants to form a balanced mycorrhizal coupling with no harm to the roots. The host provides photosynthetic products to the fungus that in turn absorbs mineral elements from the soil and makes them available to the host. Each depends on the other. Because the majority of mycorrhiza-forming fungi depend on host roots for survival, spores must be deposited on or within soil where host roots will be available to establish new colonies (Maser et al. 1978b).

Mycorrhiza-forming fungi that produce aboveground fruiting bodies and release their spores into the air are called epigeous fungi. Although spores from epigeious fungi can be moved long distances, many of them may be depostied where no host roots are available. Species that produce hypogeous (below ground) fruiting bodies have a more specialized means of spore dispersal. Fruiting bodies mature below the ground and are eaten by small animals. All tissues of a fruiting body are digested except the spores, many of which remain viable after being

passed through the animal's digestive tract. Animals defecate these spores, usually on or within soil. The spores are washed into soil by precipitation and are thus strategically placed for contact with host plant rootlets (Trappe and Maser 1978). Stomach content analysis, in which the kinds of fungi actually eaten by small mammals were identified, confirmed that hypogeous species predominate in the fungal portion of the diets (Maser et al. 1978a).

Chipmunks inhabit all forest successional stages from the Cascade Range west to the coast (Gashwiler 1959, 1970) and are known to feed extensively on a wide variety of hypogeous fungi. They are considered major dispersers of mycorrhiza-forming fungal spores (Maser et al. 1978b, McIntyre 1980). These chipmunks are capable of traveling relatively long distances in a short time and regularly visit clearcuts from surrounding cover (Gashwiler 1959, Maser et al. 1978a). Appropriate fungi are ingested in standing timber, and the spores are subsequently defecated in clearcuts where the symbiotic association with rootlets of new trees can begin. Large logs serve several important functions during the dispersal of hypogeous mycorrhiza-forming fungi. They serve as home sites and travel lanes, as well as supplying cover for the small mammals that are the primary dispersers of these fungi. Also, the decomposed logs provide suitable sites for re-establishment of colonies of hypogeous fungi (Maser et al. 1978b).

California western red-backed voles normally disappear from clearcuts within a year after logging and burning (Gashwiler 1959, 1970). It is hypothesized that they disappear because they no longer have their specialized food supply—hypogeous ectomycorrhiza-forming fungi, which do not fruit without their coniferous host (Maser et al. 1978a, 1978b). If large logs are present, voles generally start to reinvade a stand at about the time understory vegetation is being shaded out. The decaying logs provide a site in which the mycorrhizzal fungi fruit which in turn provides food for the voles. The above sequence can take place within 20 years but may require 40 years or more. Again, logs are a necessary habitat component. The stand must also be within the dispersing distance of voles from adjacent suitable habitat.

According to Zinke et al. (1979), demands for increased utilization of logging slash will cause a significant drain of nutrients from the forest. With intensified timber harvesting, more attention should be given to replenishing site fertility and to the role that dead and down woody material plays in this restoration.

Dead and Down Woody Material in Unmanaged Stands

In an unmanaged stand, logs are recruited to the forest floor by the fall of either living or dead trees (Maser et al. 1979). Large volumes of coarse woody debris are characteristic of our unmanaged forest ecosystems. Large down logs can be the dominant feature of old-growth forests, and in numbers, volume, and weight of organic matter, they are an important component (Franklin et al. 1981).

In studying a small 25-acre western Oregon watershed covered with old-growth Douglas-fir/western hemlock forest, Grier and Logan (1977) found that down logs averaged 85 tons per acre. Amounts within the watershed varied greatly; the lightest weights (25 tons/acre) occuring on a dry ridgetop and the heaviest (259 tons/acre) on a lower slope, streamside area. Losses by downslope transfer had occurred on the ridgetop, and substantial amounts of debris had accumulated on the lower slope. Franklin et al. (1981) reported that the weight of down logs from nine old-growth stands west of the Cascade Range in Oregon and Washington averaged 53 tons per acre. They also found, however, that there was only a loose correlation between the age of the stand and the weights of down logs. Some natural, young Douglas-fir stands had accumulations of down logs as large as those found in old growth. This was primarily material carried over as snags and logs from earlier stands.

Dead and Down Woody Material in Managed Stands

Since coarse woody debris persists for long periods, it provides continuity of this type of wildlife habitat from one forest generation to the next (Maser et al. 1979) as well as conserving large masses of organic matter and nutrients in areas of major disturbance. This finding suggests that the long-term ecological effects of programs that result in nearly complete removal of woody debris in cutover stands and that prevent the accumulation of new debris in intensively managed stands should be carefully examined (Franklin et al. 1981).

Timber harvesting, silvicultural practices, and land clearing operations generate forest residues on nearly 1.5 million acres annually in Washington and Oregon (Maxwell and Ward 1976). The method of logging and subsequent regeneration, along with silvicultural practices used on these stands after they are regenerated, determine the amount and distribution of forest residues that remain as wildlife habitat through stand rotation.

Logging Slash

Logging debris or slash consists of branches, foliage tops, and any unmerchantable wood left on the site such as hardwoods and cull logs. The amount and size of slash vary widely, depending on age of the harvested stand and amount of defect, logging method, and such site characteristics as slope and topography. Economic considerations, such as the distance to market and demand for pulp chips and firewood, affect the type and amount of residue left after logging. Older stands yield more residue with less sound wood than do young stands (Howard 1973).

Logging Slash in Clearcuts

Untreated slash, resulting from high-lead logging in 300-to-350-year-old Douglas-fir/western hemlock stands, ranged from 100 to over 200 tons per acre (Maxwell and Ward 1976). Second-growth timber stands generated 70 to 90 percent less forest residue during harvest than did old-growth stands (Bergvall et al. 1979).

Although logging slash is beneficial for such purposes as nutrient cycling, soil protection, wildlife habitat, and microclimate effect, excessive amounts of these residues can adversely affect forest management objectives (Maxwell and Ward 1976). This material can create a greater fire hazard, can interfere with tree planting, and may impede movements of some wildlife species. The slash provides cover for rodents and lagomorphs that may affect the success of tree regeneration. Therefore, some form of slash reduction generally follows harvest. Where slash is moderate to heavy, burning is usually the preferred method (Cleary et al. 1978). Areas that have been logged by the high-lead method are generally broadcast burned.

Yarding of unmerchantable materials is another method of slash reduction. In this program, everything down to a certain size class must be removed as a condition of the timber sale contract. This leaves only fine slash that may or may not require burning. This practice increases logging costs and increases the size of landing required. It also reduces availability of large logs that would remain as wildlife habitat through subsequent stand rotations (fig. 8).

Figure 8.—This hollow Douglas-fir stump was used by a Douglas squirrel for food storage.

Logging Slash in Partial Cuts

Residues resulting from most westside partial cuts are too abundant and uneven to treat by underburning. The objective of protecting the leave trees from intense heat can be met with greater certainty by piling and burning the residues (Henley and Clarke 1976). An occasional pile left unburned provides habitat for wildlife.

Shelterwood and seed tree cuts leave a small number of trees per acre for the purpose of providing shade and modifying the environment for planted seedlings, or to provide seed for natural regeneration. More slash treatment options can be applied to this type of stand because of the wide spacing of the leave trees.

Commercial Thinning

Commercial thinning removes trees to leave a predetermined volume per acre and to increase spacing between trees that remain. Sound logs and dead trees usually are removed during this operation. This reduces the amount of onsite material suitable for use as wildlife habitat unless an effort is made to leave certain trees, snags, and logs.

Precommercial Thinning

Slash from precommercial thinning is usually left untreated. Untreated volumes in Douglas-fir stands ranged from 7.7 to 11 tons per acre and consisted mostly of fine material less than 3 inches in diameter. This slash covered 69 to 93 percent of the ground surface at depths of 1 to 2.3 feet (Maxwell and Ward 1976). This amount of slash will reduce forage production and hinder access for many wildlife species. To hasten decomposition, slash is sometimes lopped and scattered.

Road Construction/Land Clearing Slash

Road Construction

Road construction slash contains all the elements of logging slash and is therefore similar. It includes stumps and root wads that may have a great deal of intermixed rocks and soil. This slash is accessible for mechanical treatment or piling. Important considerations in planning for the treatment of roadside debris include reduction of fire hazard, maintenance of travel routes for wildlife or domestic livestock, and access for timber management. Piled materials furnish habitat for some wildlife species (fig. 9). The debris piles can also be used as a physical and visual barrier between the road and adjacent wildlife habitats and thus can reduce disturbance created by road traffic.

Figure 9.—This hollow, class 3 Douglas-fir log provided a den for a gray fox.

Clearing and Scarification

Land clearing is an expensive operation with limited application. It is sometimes done to convert forest sites for special uses, such as outplanting sites for nursery stock or other forest experiments. Slash generated from scarification in the conversion of hardwood stands to conifers usually is windrowed on the site. Long rows of material can create serious problems by impeding movement of big game and livestock unless openings are provided. They also tend to create a shooting gallery effect on big game, especially when aligned at right angles to roads.

Fire is usually used to reduce the volume of slash. Piles that remain, however, and that contain unburned or partially burned materials, are used as denning or feeding sites by small mammals as the surrounding plant community proceeds through succession (McIntyre 1980).

Utilization of Forest Residues

Interest in the utilization of logging residues has increased dramatically in recent years. According to Grantham et al. (1974), equipment and methods available to collect, load, and transport

this material generally were uneconomical. That may have been the case in 1974, but with the increase in demand and unit price, it may no longer be true. Commercial use is usually confined to material over 8 inches in diameter and at least 8 feet in length because smaller materials are unprofitable to handle. The lowest cost per dry ton results from working only with large pieces of slash (Grantham et al. 1974).

As energy costs escalate, interest in the use of logging slash as an alternate source of energy will increase. Pilot programs to develop, demonstrate, and make available information on methods of improving wood utilization on public and private lands are being implemented (Bergvall et al. 1979). Current demand near population centers has outstripped the supply of accessible slash and hardwoods for firewood. As this demand continues to increase, stimulated by increased heating costs, techniques of collecting firewood become more diverse, and further reduce this component of wildlife habitat.

Fire and Its Effects on Wildlife Habitat

In all plant communities, fire can be a major modifier of wildlife habitat. Food, cover, water, and the total environment can be drastically affected by a high-energy fire. Generalizations regarding effects of fire on wildlife, however, are difficult because of the wide variation in the intensity, duration, and frequency of fire that can occur on a site (Lyon et al. 1978). Most of the research on the effects of fire on wildlife relates to the plant community and its modification by fire. Depending on the wildlife species involved, impacts by fire on habitat may be either beneficial or detrimental. Woody debris left after logging and land clearing has fed many recent fires in this region.

According to Dimock (1974), change in the forest environment brought about by burning of dead and down woody material probably is most directly advantageous to large mammals. This is particularly true where heavy concentrations of debris before burning may have restricted the access and mobility of large mammals. Animals whose habitat is enhanced by accumulation of coarse and fine woody debris and vegetation, however, may be adversely affected by burning. Hooven (1969) reported that some mammals and birds prefer the habitat afforded by unburned living and dead forest debris.

The benefits of fire for big game, livestock, and some smaller animals are significant:

1. The initial vegetative response will usually produce many species of shrubs and herbaceous plants that are preferred as forage;
2. The numbers of plant species available as preferred forage may be augmented;
3. Total quantity of preferred animal foods may be increased;
4. Because of a temporary increase in the supply of nutrients following burning the quality of preferred forage may be stimulated; and
5. Optimum habitability for animals may be effectively prolonged by the reversion to early successional stages of vegetation (Dimock 1974).

Wildfire

Historically, fire has played an important role in development and perpetuation of Douglas-fir forests and in modification of wildlife habitat in the Pacific Northwest. Some of the largest and most economically destructive fires in the Nation have occurred on the western slopes of the Cascade Range, in the Olympics, and along the Coast Ranges. Large areas of forest were destroyed by fires, such as the Yacolt fire in 1902 in southern Washington, and the Tillamook fires of 1933, 1939, 1945, and 1951 in northwestern Oregon. According to Kozlowski and Ahlgren (1974), large and destructive forest fires also occurred in western Oregon and Washington in 1849 and 1868.

Prescribed Burning

In western Oregon and Washington, prescribed fire is used extensively for reduction of fire hazard and preparation of sites for reforestation by one of three methods. Slash is: (1) broadcast burned—fire is set to spread with progressive ignition over a specified area, usually in unpiled slash; (2) piled by tractor or cable and burned—slash is concentrated into various arrangements of piles for ignition; or (3) underburned beneath the timber canopy with a low intensity fire that consumes most smaller fuels along with some ground vegetation and other woody forest residues.

Leopold (1950) stated that prescribed burning is the cheapest and most widely recommended tool for improving big game and livestock ranges in various parts of the United States. The beneficial effects of prescribed burning in the Pacific Northwest for deer, elk, and livestock have been documented (Garrison and Smith 1974, Harper 1971, Swanson 1970).

It must be kept in mind that the habitats created by prescribed burning favor some animals and discriminate against others. Although burning may improve access to seeds and other foods, fire is probably more neutral than beneficial to most birds. It adversely affects resting and escape cover afforded by cull logs and other down woody debris. For game

birds, production and accessibility of valuable foods may be enhanced by burning. The type of burning applied to a site has a great deal to do with the type of wildlife habitat that results from the burn. For example, broadcast burns after clearcutting may result in an initially depressed population of small mammals, which usually recovers quickly. Tractor piling and burning, on the other hand, may produce fewer impacts if some logs are left unpiled and unburned. When carefully applied, low intensity underburning of combined slash and naturally occurring woody fuels will probably result in minimal disturbance to most wildlife cover. When the potential effects of prescribed burning on wildlife habitat are being evaluated, the physical characteristics of the site must be considered. Soil type and depth, slope, exposure, moisture, and other factors make each site unique in its vegetative responses to burning. If prescribed and applied carefully, fire can produce a desirable mosaic of conditions that can enhance wildlife habitat diversity in westside ecosystems.

Direct and Indirect Effects of Fire

Although some vertebrate wildlife mortality has been recorded, a common opinion is that vertebrates are rarely killed in fires (Lyon et al. 1978). The response to fire by vertebrates is related to both mobility of the animals, and the size, intensity, and timing of the fire. Larger, more mobile animals usually move calmly away from a fire area. Smaller rodents are most likely to panic. Birds generally show no fear of fire and some are even attracted to a burning site. Burns during periods when birds are nesting and mammals are producing young can, however, have severe impacts on local wildlife populations.

The effects of fire on invertebrate populations vary; they may be brief or long lasting. In general, invertebrates decrease in numbers because they or their eggs—along with their food supply and shelter—may be destroyed by fire, depending on its duration and intensity.

The immediate effect of fire on stream habitat is usually negligible. Direct heating normally will affect only short stretches of water, and severe damage is unlikely (Hall and Lantz 1969). Stream habitat may be indirectly affected, however, by high intensity fire because of increased water flow and soil erosion, removal of protective cover, and increases in nutrient loading. Prescribed burning—with intensity, spread, and duration controlled—combined with streamside protection will greatly modify the degree of potential impacts.

Indirectly, wildlife habitat may be influenced by the long-term effects of fire. Increased light and insolation on a burned site may favor certain species; whereas other species may avoid such areas. Soil and vegetative charring after a burn may actually contribute to increased heat input to an area because of absorption characteristics of blackened ground, and thereby indirectly affect potential animal distribution and plant species composition on the site.

A considerable modification of habitat structure and local microclimate will be exhibited in the immediate postfire environment. Increased temperatures, more light, greater wind velocities, lower humidity, modified snow depths, and changes in food and cover are potential influences that require analysis and consideration on sites being planned for fire applications.

Protecting Dead and Down Woody Material

Only during the past decade have dead and down woody materials been recognized as important components of the forest environment. Investigations have shown that this material, especially large logs, serve several important biological functions within the complex forest ecosystem (Franklin et al. 1981, Maser et al. 1979).

Large logs provide wildlife habitat in the form of travel routes as well as sites for feeding, resting, and reproduction. This material also serves as sites for nitrogen fixation, nutrient cycling, and in many areas provides favorable moisture regimes for the establishment of tree seedlings and mycorrhizal fungi (Franklin et al. 1981, Maser et al. 1979).

The importance of these functions is not completely understood, but evidence suggests the health of the forest may be involved. Just because we do not fully undertand the interrelationships of components in the forest ecosystem does not make a single component less important.

There are no complete guides to the number of large logs and the amount of coarse debris that should remain on a site after timber harvest and site preparation. Defining the types and sizes of logs and other woody debris desired in managed stands is still a major research problem. There are, however, useful techniques and guidelines to which a manager can refer until better information becomes available.

Management Considerations

The following paragraphs adapted from Martin and Dell (1978) and Maser et al. (1979) offer suggestions on how management objectives for dead and down woody materials can be achieved.

Fire specialists frequently want to remove as much fuel as possible from a site to obtain maximum reduction of fire hazard. Elimination of large logs probably contributes little to hazard reduction since the greatest potential for ignition and spread of fire is among the fine fuels. Although large-diameter fuels add to the total fuel loading of a site, their fire hazard potential depends greatly on the presence of fine fuels.

There are techniques for broadcast burning in clearcuts that can be used to preserve a desirable number of downed logs for wildlife use. For example, logs for wildlife can be retained most easily if prescriptions call for burning after precipitation has occurred for an extended period.

The best time to burn and still retain logs under a timber overstory is in the spring before winter moisture has been lost. Fine fuels will have dried out and will be responding to daily fluctuations in humidity. Larger fuels will still be slightly wet and will be only partially consumed by the fire. Special protection may be required to retain logs for wildlife if they are dry. Readily combustible fuels can be raked away from the logs or fire retardants applied around them.

If a predetermined number of logs are to be left as wildlife habitat in areas to be prepared for fire prevention or control, it should be understood in the planning stage that they do not need to be uniformly distributed. For example, it may be desirable to leave some areas clear for human access or as fire lanes and fuel breaks. This can be compensated for by leaving a high density of logs in other areas. The manager has the ability to provide fuel-free areas, and at the same time, meet log requirements for wildlife habitat.

Guidelines for the management of forest residues in the Pacific Northwest have been developed for use by foresters, scientists, and technical resource specialists (Pierovich et al. 1975). Using these guidelines as a base, Maser et al. (1979) developed a series of management tips for the protection of both terrestrial and aquatic wildlife habitats created by dead and down woody material. Although these tips were developed for the Blue Mountain region, most of them are applicable to a much broader area. Therefore, with minor modifications to make them more closely conform to western Oregon and Washington conditions, they are repeated here.

1. Woody debris (slash) should be retained for wildlife cover on 10 percent of the area clearcut (Dimock 1974, Garrison and Smith 1974, Pierovich et al. 1975).
2. Slash should be reduced to a depth of 8 inches or less on at least 75 percent of an area important for big game forage production (Pierovich et al. 1975).
3. Continuous concentrations of slash larger than 3 inches in diameter or higher than 6 inches above the soil should be avoided, because they restrict the travel of big game animals (Dimock 1974, Garrison and Smith 1974, Pierovich et al. 1975).
4. A uniform 1-inch thickness of wood chips has an adverse affect on the establishment of grass seeds, herbaceous plants, shrubs, and tree seedlings (Pierovich et al. 1975, Rothacher and Lopushinsky 1974). If the chips are mulched into the soil, the carbon-nitrogen ratio will reduce growth or kill vegetation (Garrison and Smith 1974). chips should be scattered to a depth of less than 1 inch (Pierovich et al. 1975).
5. Forcing big game animals to abandon established trails because of windrowed materials should be limited to no more than 230 feet (Pierovich et al. 1975).
6. At least two uncharred class 1 or class 2 logs per acre should be retained as wildlife habitat. Furthermore, all class 3, 4 and 5 logs, which have little or no commercial value but are acceptable as fuel loading, should be retained. For a maximum function as wildlife habitat, the logs should be at least 12 to 17 inches in diameter at the large end and 20 feet or more in length. Preservation of logs in classes 3 and 4 may be easily accomplished in a manner consistent with wildlife management objectives.

   When slash is reduced to meet fuel management standards, logs are easier to save than other classes of dead and down material. Fortunately, this permits the most volatile woody material to be removed and reduces fire hazard while retaining the most important habitat component.

   With modern machinery, logs can be easily moved around and positioned to provide maximum effectiveness as wildlife habitat. For example, a log can be moved away from a slash pile to be burned, placed along the contour of a slope, or abutted against the uphill side of a sound stump. The options are many; and with ingenuity on the part of the forester and wildlife biologist, adequate dead and down habitats can be maintained with minimum economic impact and without increasing the fire hazard.
7. Under Federal and State law, streams may not be used for solid waste disposal. Retention of adequate buffer strips will protect both water quality and riparian habitat. Directional and cable-assisted felling of trees and yarding away from streams will usually prevent logging debris from entering aquatic habitats (Brown 1974, Pierovich et al. 1975).

8. The removal of natural, stable woody material, especially logs, may seriously damage the stream channel and the streamside riparian habitat. Such woody material provides excellent habitat for aquatic and amphibious wildlife and for many small terrestrial animals; it should be left in place when possible. Logs that are buried in the streambed frequently create small waterfalls and plunge pools which aerate the water and increase habitat diversity.

   Massive accumulations of large woody material can act as barriers to fish passage and cause streambank erosion, thereby damaging the streamside riparian habitat (Brown 1974, Pierovich et al. 1975). Such residues trap a significant amount of sediment and should be surveyed by competent stream ecologists and wildlife biologists before a decision is made to remove woody material (see chapter 10).

9. Timing is a critical factor in remedial work to remove woody debris from streams. The best time is during the low water period. The optimum method is to lift wood out of the stream channel and place it well above the high-water level (Pierovich et al. 1975). Least desirable is any method that involves operating vehicular equipment within a stream channel (Burke 1965).

10. Unstable woody material may accumulate behind large obstructions in a stream and cause temporary damming. Under extreme flows, dams can break and severely damage the aquatic and streamside riparian habitats (Brown 1974, Pierovich et al. 1975).

11. Unstable wood, such as logs or limbs more than 3 inches in diameter and 5 feet in length, may divert water, causing streambank erosion and damage to streamside riparian habitat (Brown 1974, Pierovich et al. 1975).

12. In contrast to unstable material, well-established logs are desirable. They provide habitat for aquatic, amphibious, and terrestrial wildlife and serve as pathways between aquatic and terrestrial habitats (fig. 10).

    Removal of such logs is detrimental to the habitat of small vertebrates dependent on the aquatic-terrestrial interface (Anderson et al. 1978, Swanson et al. 1976).

Suitable amounts and types of woody materials will be available on most sites in western forests during the conversion from old growth to managed strands and, if protected, will persist into the next rotation. As intensive timber management is applied through subsequent rotations, however, the availability of suitable materials will decline. Under these conditions, the land manager will have to consciously plan for the retention of snags and defective live trees if dead and down woody material is to continue as a viable component in future forest environments. Some authors have suggested leaving groups of defective trees, large snags, and logs that cover the spectrum of decomposition on a site in order to provide suitable pools of inoculum and to maintain continuity from one stand to the next (Cline et al. 1980, Franklin et al. 1981).

Leopold (1966) wrote of the complexity of the land organism: "If the biota, in the course of aeons has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering." Some of the "cogs and wheels" that function in western forest ecosystems are the dead and down woody materials. They should not be written off as a useless component of the system before we have a chance to fully understand and appreciate their importance.

Figure 10.—Logs serve as cover for wildlife and provide ties between aquatic and terrestrial habitats.

References Cited

Anderson, N. H.; Sedell, J. R.; Roberts, L. M.; Triska, F. J. The role of aquatic invertebrates in processing of wood debris in coniferous forest streams. Am. Midl. Nat. 100(1): 64-82; 1978.

Bergvall, J. S.; Gee, L.; Koss, W. Wood waste for energy study, Executive Study. Prepared for State of Washington House of Representatives Committee on Natural Resources. Olympia, WA; January 1, 1979. 16 p.

Brown, G. W. Fish habitat. In: Environmental effects of forest residues management in the Pacific Northwest: a state-of-knowledge compendium. Gen. Tech. Rep. PNW-24. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1974: El-E15.

Burke, M. H. M-watershed: General memorandum to K. W. Lindstedt. On file at Pacific Northwest Region, U.S. Department of Agriculture, Forest Service. Portland, OR: 1965.

Cleary, B. D.; Greaves, R. D.; Hermann, R. K. Regenerating Oregon's forests. Extension Service Publication. Corvallis, OR: Oregon State University; 1978. 286 p.

Cline, S. P.; Berg, A. B.; Wight, H. M. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. J. Wildl. Manage. 44(4): 773-786; 1980.

Dimock, E. J., II. Animal populations and damage. In: Environmental effects of forest residues management in the Pacific Northwest: a state-of-knowledge compendium. Gen. Tech. Rep. PNW-24. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1974: 01-021.

Franklin, J. F.; Cromack, K., Jr.; Denison, W. [and others]. Ecological characteristics of old-growth Douglas-fir forests. Gen. Tech. Rep. PNW-118, Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 48 p.

Garrison, G. A.; Smith, J. G. Habitat of grazing animals. In: Environmental effects of forest residues management in the Pacific Northwest: a state-of-knowledge compendium. Gen. Tech. Rep. PNW-24. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range Experiment Station; 1974: P1-P10.

Gashwiler, J. S. Small mammal study in west-central Oregon. J. Mammal. 40(1): 128-139; 1959.

Gashwiler, J. S. Plant and mammal changes on a clear-cut in west-central Oregon. Ecology 51(6):1018-1026; 1970.

Grantham, J.; Estep, E.; Pierovich, J. [and others]. Energy and raw material potentials of wood residue in the Pacific Coast States. A summary of a preliminary feasibility investigation. Gen. Tech. Rep. PNW-18. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest and Range Experiment Station; 1974. 37 p.

Grier, C. C.; Logan, R. S. Old-growth *Pseudotsuga menziesii* communities of a western Oregon watershed: Biomass distribution and production budgets. Ecol. Monogr. 47(4):373-400; 1977.

Hall, J. D.; Lantz, R. L. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. In: Northcote, T. G., ed. Proceedings, symposium on salmon and trout in streams. H. R. McMillan lectures in Fisheries; 1968 February 22-24; Vancouver, BC: University of British Columbia; 1969: 355-375.

Harper, J. A. Ecology of Roosevelt elk. Portland, OR: Oregon State Game Commission P-R Project W-59-R report; 1971, 44 p.

Henley, J. W.; Clarke, E. H. Forest residues: a manageable problem. In: Land applications of waste materials. Ankeny, IA: Soil Conservation Society of America; 1976: 98-111.

Hooven, E. F. The influence of forest succession on populations of small animals in western Oregon. In: Black, H. C., compiler and ed. Wildlife and reforestation in the Pacific Northwest: Symposium of September 1968. Corvallis, OR: Oregon State University, School of Forestry; 1969: 30-34.

Howard, J. O. Logging residue in Washington, Oregon, California: Volume and characteristics. Resour. Bull. PNW-44. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1973. 26 p.

Jones & Stokes Associates, Inc. Old-growth forests of the Douglas-fir region of western Oregon and western Washington: characteristics and management. Prepared by F. J. Lang, for North West Timber Assoc., Eugene, OR, and Western Forest Industries Assoc., Portland, OR; 1980. 62 p.

Kozlowski, T. I.; Ahlgren, C. E. Fire and ecosystems. Effects of fire on temperate forests; western United States. New York; Academic Press; 1974. 542 p.

Leopold, A. S. Deer in relation to plant succession. J. For. 48(10):675-678; 1950.

Leopold, A. A Sand County Almanac with other essays on conservation from *Round River*. New York: Oxford University Press; 1966. 269 p.

Lyon, L. J.; Crawford, H. S.; Czuhai, E. [and others]. Effects of fire on fauna – a state-of-knowledge review. National Fire Effects Workshop; 1978 April 10-14; Denver, CO. Gen. Tech. Rep. WO-6. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978. 22 p.

McIntyre, P. W. Population structure and microhabitat utilization of *Eutamias siskiyou* within a variously treated shelterwood cut. Ashland, OR: Southern Oregon State College; 1980. 113 p. Thesis.

MacMillan, P.; Means, J.; Hawk, G. M. [and others]. Log decomposition in an old-growth Douglas-fir forest. Northwest Sci. Assoc. Program and Abstr. of the papers scheduled for presentation at the 50th Annual Meeting; 1977. p. 13.

Marcot, B. G., ed. California wildlife/habitat relationships program, North Coast/Cascades zone: introduction. Eureka, CA: U.S. Department of Agriculture, Forest Service, Six Rivers National Forest; 1979. 133 p.

Martin, R.; Dell, J. Planning for prescribed burning in the inland Northwest. Gen. Tech. Rep. PNW-76. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1978. 67 p.

Maser. C.; Anderson, R. G.; Cormack, K., Jr. [and others]. Dead and down woody material. Chapter 6. In: Thomas, J. W., tech.ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture; 1979: 78-95.

Maser, C.; Trappe, J. M.; Nussmaum, R. A.; Fungal-small mammal interrelationships with emphasis on Oregon coniferous forests. Ecology. 59(6):799-809; 1978a.

Maser, C.; Trappe, J.; Ure, D. Implications of small mammal mycophagy to the management of western coniferous forests. 43d North Am. Wildl. and Nat. Resour. Conf. Trans.: 78-88; 1978b.

Maxwell, W. G.; Ward, F. R. Photo series for quantifying forest residues in the: Coastal Douglas-fir-hemlock type—Coastal Douglas-fir-hardwood type. Gen. Tech. Rep. PNW-51. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1976. 103 p.

Pierovich, J. M.; Clarke, E. H.; Pickford, S. G.; Ward, F. R. Forest residues management guidelines for the Pacific Northwest. Gen. Tech. Rep. PNW-33. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1975. 281 p.

Roskoski, J. P. Nitrogen fixation in northern hardwood forests. New Haven, CT: Yale University; 1977. 112 p. Dissertation.

Rothacher, J.; Lopushinsky, W. W. Soil stability and water yield and quality. In: Environmental effects of forest residues management in the Pacific Northwest: a state-of-knowledge compendium. Gen. Tech. Rep. PNW-24. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest Range Experiment Station; 1974: D1-D23.

Swanson, D. O. Roosevelt elk-forest relationships in the Douglas-fir region of the southern Oregon Coast Range. Ann Arbor: University of Michigan; 1970. 186 p. Dissertation.

Swanson, F. J.; Lienkaemper, G. W.; Sedell, J. R. History, physical effects, and management implications of large organic debris in western Oregon streams. Gen. Tech. Rep. PNW-56. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1976. 15 p.

Trappe, J. M.; Maser, C. Ectomycorrhizal fungi: interactions of mushrooms and truffles with beasts and trees. In: Walter, T., ed. Mushrooms and man, an interdisciplinary approach to mycology. Albany, OR: Linn-Benton Community college; 1978: 163-169.

Zinke, P. J.; Stangenberger, A.; Colwell, W. The fertility of the forest. California Agriculture. 33(5): 10-11; 1979.

9

Caves, Cliffs, and Talus

Raymond W. Scharpf
Fred C. Dobler

Table of Contents

Introduction

Most wildlife habitats within forest ecosystems are defined by the vegetative components of the forest, its stand characteristics, and successional stages. Geological features, however, also create habitats in which the primary elements are nonvegetative. Plants contribute to the usability of these communities but it is the geological features which set them apart from others. Maser et al. (1979b) called these "unique habitats" and points out that although covering relatively few acres, they contribute significantly to the diversity of wildlife found in the forest environment.

"Unique habitats" found in the Coast and Cascade Mountain ranges include caves, cliffs, and talus slopes (fig. 1). These habitats provide refuge for many wildlife species, some of which are so dependent upon these geomorphic features, they are not found elsewhere. Ordinarily, caves, cliffs, and talus slopes are more resistant to change than plant communities. Either a cataclysmic natural event, such as the volcanic eruption of Mount St. Helens, or an intense effort by man, such as a mining operation, is required to alter the geomorphic structure of these unique habitats. Though their structure may not change, man's activities regularly alter the ecosystems within which these unique habitats occur. Maser et al. (1979b) points out that once destroyed, most geomorphic habitats are difficult to create artificially and replacing them usually is not economically practical.

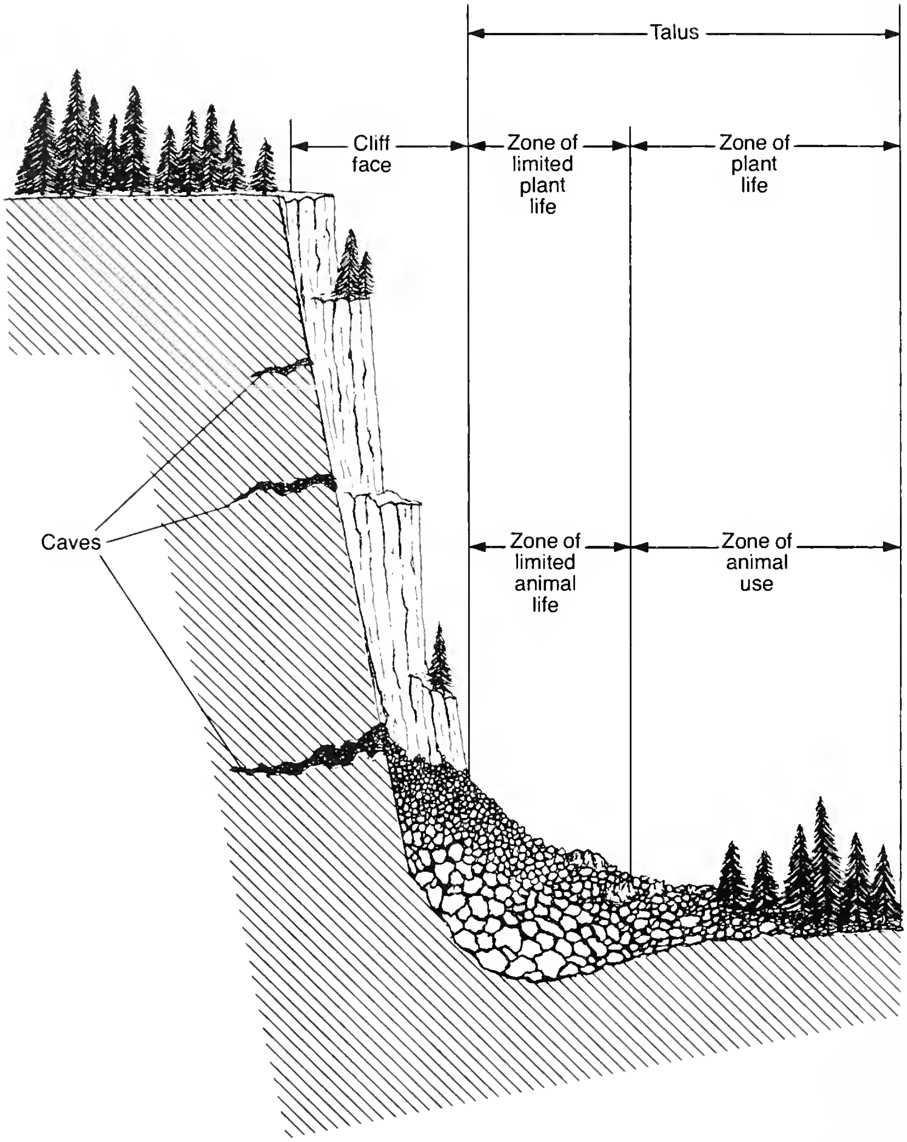
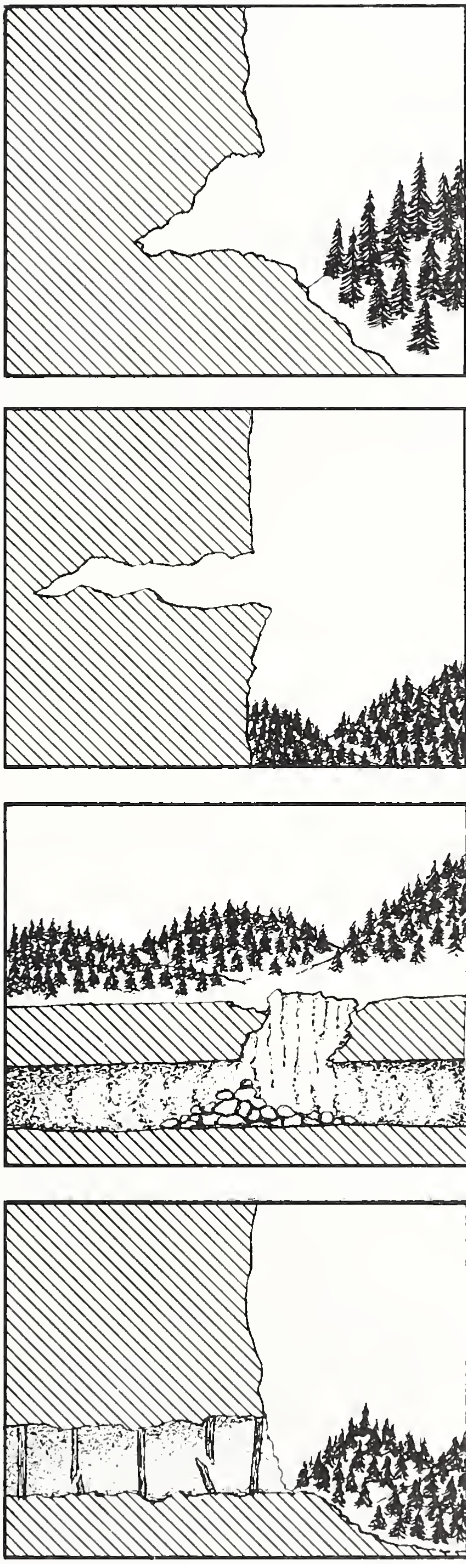


Figure 1.—Cave, cliff and talus (Adapted from Maser 1979a, fig. 16 and 17, p. 10).

Caves

Caves are unique habitats for wildlife since their recesses provide a more stable environment of temperature and moisture than do most terrestrial habitats (Barr 1964, Barr 1967, Nichols 1955). Many of the obligate cave dwellers such as the bats are poikilothermic (their body temperatures vary with the air temperature). Consequently, they are extremely dependent upon this stability to maintain their bodily functions. Those that use caves simply as a matter of preference or convenience such as the bobcat, depend on this stability to a lesser degree, but it is still an important habitat element (fig. 2).

Although not obligate cave dwellers, raptorial birds like the owls use shallow caves and the entrances to deeper caves for roosting and sometimes nesting (Guilday and Parmalee 1965). Preferred sites are the shallow caves that occur in eroded sedimentary rock or sandstone and along thrusted cliffs of igneous, basalt, andesite, or rhyolite rock.



TYPE	FAUNA	USES
Shallow caves and ledges	Bats	Roosting, breeding and hibernation.
	Raptors	Roosting, nesting and perching.
	Bobcats	Shelter and breeding.
Cliff-face caves	Bats	Roosting, breeding and hibernation.
	Woodrat	Shelter and breeding.
Lava tubes	Bats	Roosting, breeding and hibernation.
	Mice Woodrats Pika Porcupine	Shelter, breeding and nesting.
Man-made mine shafts	Bats	Roosting, breeding and hibernation.
	Mice Woodrats Pika Porcupine	Shelter, breeding and nesting.

Figure 2.—Types of caves and cliffs and examples of associated wildlife (Adapted from Maser 1979a, fig. 10, p. 7).

Lava tubes and solution caves caused by the corrosive action of acidic ground water are usually deeper and provide the environment that true cave dwellers require (fig. 3). The twilight zone (fig. 4) of these caves supports a few plants, such as lichens and ferns, and a diversity of wildlife species (Poulson and White 1969). These include bats, small birds, insects, native cats, rodents, and amphibians, most of which forage outside the cave (Nicholas, 1955). While most twilight zone inhabitants leave the cave for foraging, they are born, raised and often die in caves (figs. 5 and 6).

Deep within the cave is the zone of total darkness. Here the only plants that grow are a few chemosynthetic autotrophs, such as bacteria, which use chemicals rather than light as an energy source for metabolism. Animals living in this zone are highly adapted to life in this stable environment. These include worms, insects, small crustaceans, snails, fish, and amphibians, some of which are unlike anything seen in the outside world (Benedict 1980). In some cases, a species found in the dark zone of a particular cave is not found outside that cave system.

Figure 3.—Typical cave entrance in a forested area of western Washington.

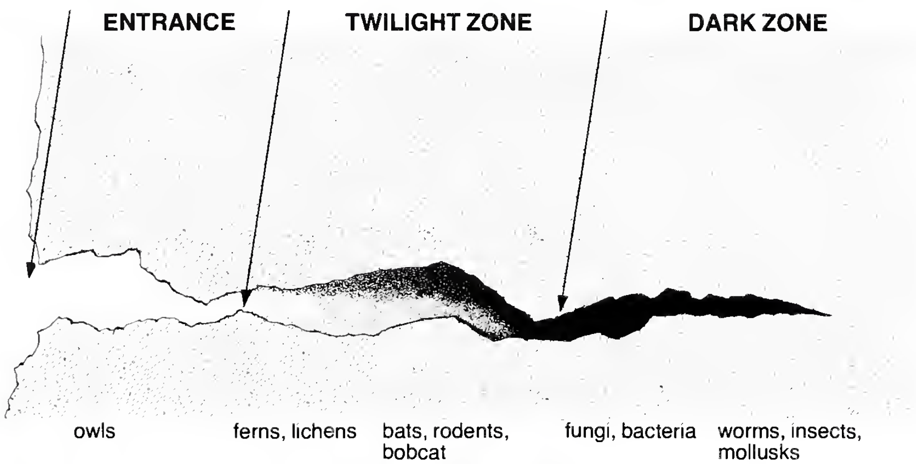


Figure 4.—Diagram of a cave showing zones and representative examples of life forms present.

Figure 5.—The northwestern salamander is an example of a cave user.

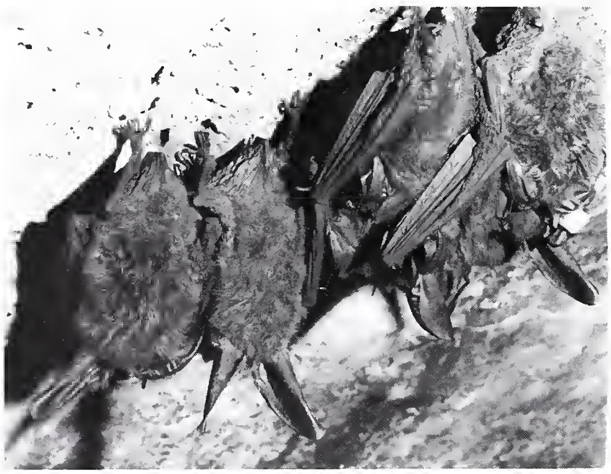


Figure 6.—Bats are common cave dwellers.

Table 1—Representative wildlife species that use caves[1]

SPECIES	ORIENTATION[2]	ZONE[3]
Amphibians		
northwestern salamander	- - f - r	E - T - -
Pacific giant salamander	- - f - r	E - T - -
Pacific treefrog	- - f - r	E - - - -
Birds		
turkey vulture	B - - - r	E - - - -
golden eagle	b - - - -	E - - - -
common barn owl	b - - - r	E - - - -
great horned owl	b - - - -	E - - - -
black swift	B - - - -	E - - - -
rosy finch	- - - - r	E - - - -
Mammals		
pallid bat	B - - - R	- - T - D
big brown bat	B - - - R	- - T - D
silver-haired bat	- - - - r	- - T - D
California myotis	B - - - R	- - T - D
long-eared myotis	b - f - r	- - T - D
Keen's myotis	B - - - R	- - T - D
little brown myotis	B - f - R	- - T - D
fringed myotis	B - - - R	- - T - D
long-legged myotis	b - - - R	- - T - D
Townsend's big-eared bat	B - f - R	- - T - D
Brazilian free-tailed bat	- - f - -	E - T - D
coyote	B - f - R	E - T - -
gray fox	b - - - r	E - T - -
black bear	b - - - r	E - T - -
ringtail	B - F - R	E - T - -
wolverine	B - F - R	E - T - -
marten	b - f - r	E - T - -
mountain lion	B - - - R	E - T - -
bobcat	B - - - R	E - T - -

[1] References: Bent 1964; Bernard and Brown 1977; Burt and Grossenheider 1976; Guenther and Kucera 1978; Halliday 1963; Ingles 1967; Kritzman 1977; Maser et al. 1981; Reed 1965; Stebbins 1966; Wilson 1975.

[2] Orientation:
B - Breeding (Primary) F - Feeding (Primary) R - Resting (Primary)
b - breeding (Secondary) f - feeding (Secondary) r - resting (Secondary)

[3] Zone:
E - Entrance T - Twilight D - Dark

Although a cave's dark zone population may appear to be completely independent of the outside world, the basic essentials for life in this zone must come into it from the outside through the twilight zone. As Barr (1967) points out, if a cave is sealed and this flow of nutrients from the outside is cut off, virtually all life within the cave will soon be lost.

At first glance, caves seem to be insulated from the impacts of forest practices; however, the environment within a cave is a fragile microcosm and easily affected (Tuttle and Stevenson 1978). Roberts (1974) points out that the simpler the ecosystem, the more vulnerable it is to change. Small changes in the transport of biological material into or out of the cave, could lead to drastic changes in resident species (Wilson 1978). Even alterations in wind currents around a cave entrance can affect the delicate balance of the micro-environment within the cave.

Nieland (1982 personal communication) has observed a marked decrease in nutrient input into shallow lava tube caves (ones with thin ceilings) in southwest Washington following timber harvest over them. He speculates that tree roots that penetrate through cracks and hang from the ceilings of these caves provide a nutrient source for invertebrate species. The harvest of trees whose roots protrude into the caves has an obvious effect on the species living in the cave.

Animals which use the cave's entrance along with twilight zone dwellers who feed outside, contribute to the organic litter deposited on the cave's floor. This in turn supports other life in the deeper portions of the cave (McAlpine and Reynolds 1977). The rate of this influx of materials influences the cave's diversity and productivity. Therefore, changes in forest structure and productivity around a cave may influence not only those species moving in and out of the cave, but the obligate cave dwellers as well. Table 1 shows the orientation and zone of use for some representative wildlife species known to use caves.

With shallow caves, removal of vegetation around the entrance can alter the light intensity and ultraviolet rays that penetrate the cave and thus impact the wildlife species using this habitat. The increased light could affect humidity

patterns, enlarge the twilight zone and reduce the dark zone. The enlarged twilight zone, coupled with a lower humidity, could make the cave more attractive to a species such as the bobcat, while at the same time those unique species occuping the dark zone would be decreased at least in proportion to the reduced size of this zone.

Another potential for change involves the seeps and small streams of deep caves. These streams distribute organic material and serve as avenues for animal distribution (Barr 1967, Poulson and White 1969). A change in the hydrologic characteristics of a drainage where a cave system occurs could alter the cave ecosystem. In addition, pesticides, herbicides, fertilizers, and other chemical pollutants can enter a cave system via the water with potentially damaging effects to its inhabitants (Wilson 1978).

Human visitation must also be considered as a disturbance factor (Mohr 1976). Cave systems can be disrupted to a much greater degree than most other habitat types because of the confined space involved, limited escape routes for species using caves, and the fragile ecosystems within caves. Roads constructed for timber harvests may make secluded caves more accessible to the public, thus increasing the chance for human disturbance. In some cases roads have been constructed directly over caves with shallow ceilings such as lava tubes, and this is extremely disruptive to the cave inhabitants.

Cliffs

A cliff is a steep vertical or overhanging face of rock (fig. 7). Many animals utilize the features of cliffs, but little work has been done to document the importance of cliffs to forest wildlife communities. Most of the animals oriented to cliffs use the security found in cracks and ledges of the cliff face to escape from predators. Birds build their nests and small mammals make dens along rocky ledges. Many raptors prefer cliffs for nesting and roosting, because the height of cliffs aids their hunting by giving them a larger field of view and providing them with predictable updrafts and thermal currents for soaring. Species that require or prefer cliff-type habitats are identified in appendix 8.

Maser et al. (1979a) classified cliffs on the basis of size (height and length), geological material forming the face, and the extent to which cliffs were fractured or pocketed. Wildlife use increases in direct relation to the size and number of fractures, pockets, and ledges formed on the cliff face. For example, the peregrine falcon uses only large fractures while American kestrels, swifts and bats utilize smaller cavities and fractures. A cliff with both large and small fractures could provide habitat for all of these species.

The type of parent material in a cliff formation is an important factor in determining the value of that cliff for wildlife. Volcanic activity in the Cascade Mountains has formed many cliffs of igneous material which is highly resistant to erosion. During cooling, this type of material often developed bubbles, crystals, and irregularities which created long-lasting ledges and fractures. Conversely, sedimentary rock, which is the most common parent material for cliffs in the Coast Ranges, is soft and subject to rapid erosion. Because of their stability and persistance, cliffs formed from igneous material are usually more valuable for wildlife habitat than those formed from sedimentary materials.

Size is another major factor affecting a cliff's value as habitat for wildlife and is nearly as important as the availability of ledges and fractures. A long, tall cliff has more area and therefore the probability of greater geologic diversity. Large cliffs also have other attributes: there is a larger overview for raptorial birds because of height and length, there is increased security from disturbance, and there are more predictable updrafts.

Elevation above sea level also governs the use of cliffs by wildlife. The peregrine falcon depends heavily upon cliff habitat for nesting, and although many cliffs occur in the Cascade Range, only those below about 5,000 feet in elevation offer much potential for nesting. The same applies to most other westside raptors.

Figure 7.—Typical igneous rock cliffs showing fissures and ledges.

At higher elevations heavy snow packs and short growing seasons limit the forage base for wildlife, which probably accounts for this altitudinal selectivity. Because of this selectivity, most cliff habitats preferred by wildlife will fall within the managed forest. Therefore, the land manager should not ignore lower elevation cliffs in land use planning even though there may be an abundance of cliffs above 5,000 feet in the area. Aspect may also be a factor, but little work has been done to determine the effect of aspect and exposure on cliff habitats.

At sea level, cliffs often exhibit spectacular significance. Coastal cliffs support colonies of birds which may number several thousand in a single location (Wilson 1980). These birds, including gulls, cormorants and murres, often range far at sea, returning to the coastal cliffs and islands to raise their young (fig. 8).

Figure 8.—Cormorants and gulls using sea cliff habitat for resting.

Raptors, including the great horned owl, commonly use cliffs for both nesting and perching sites.

Forest practices can have both direct and indirect impact upon the use of cliffs by wildlife. The most common direct impact involves blasting and quarrying of cliffs to provide crushed rock for improvement of logging roads. Disturbance as a result of a quarry operation usually extends beyond the actual site itself. Also, because quarry sites tend to be used over long periods of time, the impacts will continue as long as the quarry is active. This is especially true where large raptors are using a cliff chosen for a quarry site.

Indirect impacts from forest practices are associated with removal of the forest habitat surrounding the cliff. When the forest is removed, the cliff environment can be altered in several ways. Wind and temperature patterns may be altered, visual barriers removed, and drastic changes will occur in the food availability for most cliff dwellers. Disturbance factors will increase; directly by the forest management activities themselves, and indirectly as the result of greater human access made possible by these forest management activities. The impacts can be either beneficial or detrimental depending on the species involved. Cliff dwellers that depend on forested areas for their forage base would be negatively impacted while those utilizing earlier successional stages could be benefited.

Talus

Talus is dislodged rock fragments that accumulate at the base of steep slopes or cliffs. It occupies a relatively small portion of the land base yet concentrates vertebrate wildlife species such as reptiles, amphibians, birds, and small mammals. Several man-made structures such as streambank rip rapping, highway and railroad grade fills, and hardrock mine tailings simulate talus and create similar wildlife habitats.

The pika is a common resident of talus.

Table 2—Talus class, based on the predominant or most common rock size in the talus field[1]

Talus Class	Rock Size (diameter)
I	less than 1.6 feet
II	1.6 - 3.3 feet
III	3.3 - 6.5 feet
IV	6.5 feet and greater

[1] Adapted from Maser et al. 1979a, Table 4, pg. 10.

For wildlife, the important structural components of talus are the type and size class of rock; the depth, width, and length of the formation; and its stability (Maser et al. 1979a). The older the talus, the more stable the formation. Most old talus slopes are in a reduced building process because the upslope areas have stabilized.

Stable talus composed of large angular rocks in deep masses creates the best wildlife habitat because of the size and depth of space between the rocks. Basalt and andesite parent material generally create this type of talus and are found primarily in the Cascade Range. In the Coast Ranges most talus is created from sedimentary rock formations which erode easily and are not as stable. Talus formed under these conditions is composed of finer material which provides limited amounts of living space for wildlife.

Maser et al (1979a) classified talus into four classes (table 2). Each class is based on the predominant or most common rock size within the talus formation. The rock size determines the space between rocks, which in turn determines the size of wildlife species that can inhabit talus. According to Bailey (1936), the yellow-bellied marmot's favorite home is a sloping mass of huge, broken and angular blocks of talus at the base of a lofty cliff (Class III or IV talus).

Bailey (1971) also reported finding that pika could run as freely and rapidly through the crevices between rocks in a talus formation as over the surface. While the western skink regularly uses Class II talus-sized rocks as lookout points, the hoary marmot prefers Class III or larger-sized talus for the same purpose (fig. 9). Species that require or prefer talus or talus-like habitats for breeding, feeding or resting are identified in appendix 8.

The small amount of area that is taken up by talus is illustrated on the Cowlitz Planning Unit of the Gifford Pinchot National Forest. On this unit, located southwest of Mount Rainier National Park in relatively rugged terrain, talus accounts for only about five percent of the total land area (USDA 1979). Other areas will vary but most will probably have even less of their total land base composed of talus.

Figure 9.—A talus slope characteristic of those occurring in the Cascade Mountains.

Talus-Like Habitats

In addition to talus fields, there are several talus-like habitats, some that are natural and others that are man-made. These consist of lava stringers, collapsed lava tubes, mine tailings, roadside fill, and riprap structures. Most of these habitats are associated with the smaller rock size classes.

Lava Stringers

Lava stringers are natural formations consisting of elongated concentrations of surface rock with similar structural components to talus. Rocks are usually Class I in size, composed of basalt, and are often, but not always, associated with cliffs. Since the lava stringers are generally composed of small rock, only relatively small wildlife species such as the golden-mantled ground squirrel or the western fence lizard can occupy them.

Collapsed Lava Tubes

Collapsed lava tube talus is also a natural formation and consists of fragments that have fallen from the tube's ceiling, forming rock piles on the floor. These piles are usually composed of Class I and II rocks. Since this form of talus occurs within lava tube caves and is usually some distance from herbaceous vegetation or other food sources, wildlife species using it will be limited. Mammals that have been observed using this habitat are deer mice, bushy-tailed wood rats, pika, and porcupines.

Mine Tailings

Mine tailings from hard-rock mines have similar structural components to Class I and II talus, but fine material which also results from the mining activity tends to fill much of the interspacing between rocks. This decreases living space for wildlife and limits its use. Early placer mining along rivers also created piles of Class I talus, but because of the small particle size and restricted interspacing between rocks, these areas have only limited wildlife value. Some species, however, such as the western toad and the yellow-pine chipmunk do utilize this type of habitat.

Road Fills

Roadside "talus" formed by road or railroad construction activities consists of rock in Classes I and II and is important to a variety of wildlife species (fig. 10). This man-made, talus-like formation can act as a connector between natural formations, extending the range of wildlife species such as the pika.

Figure 10.—Road fills form talus-like structures that act as a connector between areas of natural talus and extend the range of wildlife species.

Riprap

Riprap talus-like formations consists of rock up to Class III, and are constructed along streams and rivers to reduce stream bank erosion (fig. 11). They usually contain large spaces between rocks but often provide only temporary habitat for terrestrial wildlife populations because of periodic inundation by water. On the other hand this type of material may provide refuge and rearing space for various aquatic species (see chapter 10).

Figure 11.—Riprap talus-like structure provides only temporary habitat along Cascade streams because of periodic inundation by water.

Effects of Forest Practices

Forest practices can have positive as well as negative effects on talus and talus-like habitats. Road construction talus, riprap structures, and mine tailings are ways by which man's activities have duplicated natural talus. The most common negative effect on natural talus involves quarrying for road construction and maintenance material. Quarrying of talus reduces the size of areas occupied by wildlife populations and often continues over long periods. Harvesting of timber adjacent to talus may not have a direct effect on talus itself, but food source availability for wildlife species occupying talus will be altered. These changes in food sources can be beneficial or detrimental depending on the species involved and the circumstances at the particular site. Other factors such as changes in wind currents, ultra violet light, and the impact of human harassment are difficult to quantify but can also affect the wildlife species utilizing talus habitats.

Figure 12.—Logging debris piles have extended the pika range.

One unusual effect of forest practices has been the adaptation to debris piles left following logging of two wildlife species that normally prefer talus or talus-like habitats. These are the pika (Jones 1977) (fig. 12) and the rock wren (Marshall and Horn 1973). This has permitted, at least temporarily, an expansion of the range of these species into habitats they would not normally use. How long this use will continue is not known but pika have continued to use one such area for three years (Jones 1977).

Management Considerations

Caves, cliffs and talus are considered "unique habitats" that occupy a very small portion of the landscape but contribute significantly to the diversity of wildlife habitat found in the forest environment. These geomorphic features provide refuge for a wide variety of wildlife species, some of which are not found except in conjunction with these habitats. Although many species utilize these "unique habitats," little work has been done to quantify their importance to forest ecosystems.

The geomorphic features of these habitats may be fairly stable but the microclimates within them are very fragile and easily affected by outside disturbance. Even small changes in and around these features can lead to drastic changes in their indigenous fauna.

Removal of forests adjacent to these geomorphic features, alters food sources, changes wind currents, affects light patterns and periodicity, removes visual barriers, modifies drainage patterns, and opens the area to increased human harassment, all of which impact the wildlife species utilizing these habitats. These factors may be beneficial to some species and detrimental to others. In the case of caves, changes in the environment surrounding the cave will affect not only those species moving in and out of the cave but the obligate cave dwellers as well.

If the goal of the land manager is to maintain stable environments within "unique habitats," the forest environment adjacent to the habitats must remain stable. Where circumstances dictate some manipulation of the environment in or around these habitats, there are several options that can reduce impacts on wildlife.

Road construction should be routed away from "unique habitats." Rock and gravel quarries should be located at sites exhibiting the least desirable characteristics as wildlife habitat. An example would be unstable areas in sedimentary rock having large amounts of fine material. Logging activities adjacent to cliffs should be carried out during periods of the year when breeding birds are not present. Roads that permit public access to secluded cliffs or caves that might be subject to human disturbance, should be closed.

Removal of timber adjacent to cliffs or talus slopes, from around the entrances to caves, or from over caves with thin ceilings should be carefully evaluated. Points to consider are how this removal would alter light intensity, wind currents, drainage patterns, humidity, food sources, and in the case of caves, how the transport of nutrients into the cave would be impacted.

Spelunking (cave exploring) and rock climbing activities may need to be regulated at certain seasons of the year to prevent disturbance of sensitive wildlife species in caves and on cliffs. Spelunker activity in caves where bats are wintering has caused the bats to abandon some caves (Senger 1980) and rock climbers may disturb nesting raptors during the spring and summer months. Limiting recreational use to non-critical time periods would be desirable.

The land manager should recognize "unique habitats" as rare features in the landscape that should be protected. During the planning stages of a project that could impact one or more of these habitats, their importance to wildlife should be evaluated and these factors taken into consideration in the design of the project. Forestry operations should not be incompatible with protection of these "unique habitats" if wildlife values are recognized and considered.

Illustrations

Figures 1, 2, and 4 by Siobhan Sullivan.

References Cited

Bailey V. The mammals and life zones of Oregon. Washington, DC: U.S. Department of Agriculture; 1936. 160 p.

Bailey V. Mammals of the Southwestern United States with special reference to New Mexico. New York: Dover Publications, Inc.; 1971. 66 p.

Barr, T. C., Jr. Cave ecology. Science. 144 (3616): 321-322; 1964.

Barr, T. C., Jr. Observations on the ecology of caves. American Naturalist. 101: 475-491; 1967.

Benedict, E. Biological resources of caves with an emphasis on biota of the Pacific Northwest. In: Sim, M.; Sim, L. compilers and eds. Far west cave managment symposium proceedings; 1979 October 23-26. Redding, CA. Oregon City, OR; 1980: 17-22.

Bent, C. A. Life histories of North American cuckoos, goatsuckers, hummingbirds and their allies. Part II. New York: Dover Publications, Inc.; 1964. 506 p.

Bernard, S. R.; Brown, K. F. Distribution of mammals, reptiles, and amphibians by BLM physiographic regions and A. W. Kuchler's associations for the eleven western states. Tech. Note. Denver, CO: U.S. Department of the Interior, 1977. 169 p.

Burt, W. H.; Grossenheider, R. P. A field guide to the mammals, field marks of all North American species found north of Mexico. 3d ed. Boston: Houghton Mifflin; 1976. 289 p.

Guenther, K.; Kucera, T. E. Wildlife of the Pacific Northwest, occurrence and distribution by habitat, BLM District and National Forest. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1978. 128 p.

Guilday, J. E.; Parmalee, J. E. Animal remains from Sheep Rock Shelter, Huntington County, Pennsylvania. Pennsylvania Archaeologist. 35: 34-49; 1965.

Halliday, W. R. Caves of Washington. Olympia, WA: State of Washington, Department of Conservation, Division of Mines and Geology; Information Circular 40; 1963. 132 p.

Ingles, L. G. Mammals of the Pacific States: California, Oregon and Washington. Stanford, CA: Stanford University Press; 1967. 506 p.

Jones, M. A new source of seedling damage in high elevation plantations. 1977; Unpublished report on file with the Weyerhaeuser Company, Forestry Research Center, Centralia, WA. 2 p.

Kritzman, E. B. Little mammals of the Pacific Northwest. Seattle, WA: Pacific Search Press/Nature; 1977. 120 p.

Marshall, D. B.; Horn, K. Adaptations of two desert birds to clearcut area in the Oregon Cascades. Murrelet. 54(3): 36-37. 1973.

Maser, C.; Geist, J. M.; Concannon, D. M.; [and others]. Wildlife habitats in managed rangelands - The Great Basin of Southeastern Oregon, geomorphic and edaphic habitats. Gen. Tech. Rep. PNW-99. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979a. 84 p.

Maser, C.; Rodiek, J. E.; Thomas, J. W. Cliffs, talus and caves. In: Thomas, J. W., tech. ed. Wildlife habitats in managed forests: The Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture; 1979b: 96-103.

Maser, C.; Mate, B. R.; Franklin, J. F.; Dyrness, C. T. Natural history of Oregon coast mammals. Gen. Tech. Rep. PNW-133. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 496 p.

McAlpine, D. F.; Reynolds, J.W. Terrestrial oligochaeta of some New Brunswick caves with remarks on the ecology. Canadian Field-Naturalist. 91(4): 366-377. 1977.

Mohr, C. E. The protection of threatened cave bats. National Cave Management Symposium Proceedings; 1975 October 6-10; Albuquerque, NM. Albuquerque, NM: Adobe Press; 1976: 57-62.

Nicholos, B. G. Life in caves. Scientific American. 195(5): 98-106; 1955.

Nieland, J. Personal Communication. Visitor Information Specialist, Mount St. Helens National Volcanic Area. U.S. Department of Agriculture, Forest Service, Gifford Pinchot National Forest, Amboy, WA. 1982.

Poulson, T. L.; White, W. B. The cave environment. Science. 165: 971-980. 1969.

Reed, C. A. North American birds' eggs. New York: Dover Publications, Inc.; 1965. 373 p.

Roberts, A. Stability of a feasible random ecosystem. Nature. 251 (5476): 607-608; 1974.

Senger, C. M. Observations on the cave basalt lava flow, Mt. St. Helens. Bull. 15. Seattle, WA: Washington Speleological Survey; 1980: 1-6.

Stebbens, R. C. A field guide to western reptiles and amphibians: field marks of all species in western North America. Boston: Houghton Mifflin; 1966. 279 p.

Tuttle, M. D.; Stevenson, D. E. Variation in the cave environment and its biological implications. National Cave Symposium Proceedings; 1977 October 3-7, Big Sky, MT. Albuquerque, NM: Adobe Press; 1978: 108-121.

U.S. Department of Agriculture, Forest Service. Environmental Statement, Cowlitz Planning Unit, Land Management Plan. Vancouver, WA: U.S. Department of Agriculture, Forest Service, Gifford Pinchot National Forest; 1979. 271 p. + appendix.

Wilson, J. Caves and cave fauna. Bull. 11. British Cave Research Association; 1975: 8-9.

Wilson, J. Caves: changing ecosystems? Studies in Speleology. 3(1): 35-42; 1978.

Wilson, U. Investigations on the outer coast of Washington, 1979-1980, Summary Report. Ilwaco, WA: Department of the Interior, Fish and Wildlife Service, Willapa National Wildlife Refuge; 1980. 31 p.

10

Salmonids

Fred H. Everest
Neil B. Armantrout
Steven M. Keller
William D. Parante
James R. Sedell
Thomas E. Nickelson
James M. Johnston
Gordon N. Haugen

Table of Contents

Introduction

Forest managers may choose to protect or enhance habitats for selected "featured" species or groups of species. The salmonids (salmon and trout) of the Pacific Northwest form an assemblage of species that deserve consideration as featured species because of their widespread contribution to both sport and commercial fishing. This chapter suggests how salmonid habitat can be protected in managed forests.

The material presented applies directly to forested lands of Oregon and Washington from the Pacific Ocean to the crest of the Cascade Range. The information can also be reasonably applied to other similarly forested lands along the Pacific Coast. Toews and Brownlee (1981) have developed similar information for British Columbia. Salmonid habitats in these areas consist primarily of cool streams and rivers, large and small mountain lakes, lowland lakes or ponds, a variety of sizes and types of reservoirs, estuaries, and the ocean. The freshwaters of western Oregon and Washington contain 16 species of salmonids and more than 50 species of nonsalmonid fishes.

Based on life-history patterns, the salmonids can be divided into two groups: anadromous and resident. Species that spawn in freshwater but spend most of their adult lives in the ocean are termed "anadromous." Both groups are widely distributed in western Oregon and Washington. Several species have both anadromous and resident forms, such as the sockeye salmon with its freshwater form, kokanee, and the rainbow trout with its anadromous form, steelhead.

Forest management activities can have profound effects on aquatic ecosystems and salmonid habitat. The interactions between timber management and salmonid habitat have been studied for about two decades and some important effects have been quantified, but many questions remain unanswered. Early studies documented that timber harvest and road construction near streams could raise water temperatures and add sediment in stream channels, with a resultant decrease in fish production. In a few instances where timber was felled directly into streams, large accumulations of fine organic debris were shown to have a negative effect on salmonids. These observed changes resulted in an imposing list of State and Federal laws, regulations, guidelines, and recommended practices that apply to timber management in the vicinity of streams. The intent of this assemblage of rules is to protect water quality and the productivity of fish habitat in a watershed while forests are cultured and harvested on a sustained basis.

Current rules regulating forest practices apply to all timber harvest operations, yet considerable latitude exists in application of the rules. For example, a variety of roading, felling, and yarding techniques can be used to harvest timber while still satisfying regulations for protection of other resources at any given location. Selecting optimum practices is often difficult for forest managers, however, because the effects of timber harvest on the aquatic environment may not be obvious and are often overlooked. Links between watershed manipulations and fish production are complex and depend on many environmental variables. Combinations of physical, climatic, and biological factors, interacting simultaneously, can have either additive, multiplicative or offsetting effects. Therefore, exact consequences of forest management are difficult to predict. Although this chapter will discuss in general the relation of timber management to salmonid habitat, management activities at specific locations should be planned by an interdisciplinary group including a trained aquatic ecologist.

Optimum habitat conditions for most salmonids are known and can be used as a comparative standard for habitats in managed forests. If conditions in managed habitats deviate substantially from established optima for a species, productivitiy in that habitat is probably below potential. This chapter will describe habitats utilized by salmonids, optimum habitat conditions for each species, effects of forest management on habitat, and procedures for maintaining or reestablishing optimum habitat in managed forests.

The following broad assumptions apply:

- The demand for salmonids by sport and commercial fisheries will increase.
- The majority of salmonid habitats in the western portions of Oregon and Washington are in streams on forested lands.
- Demand for multiple resources from forested lands will continue to create potential conflicts between timber and fishery management.
- Spawning and rearing habitats and migration routes are the primary habitat features limiting freshwater production of salmonids.
- Characteristics of salmonid habitat such as the quantity and quality of water, riffles, pools, substrate, cover, and food can be negatively impacted by forest management.
- Simultaneous production of timber and salmonids can be accomplished on the same units of land with carefully planned and executed management.

Geomorphology of Salmonid Habitats

The aquatic systems of western Oregon and Washington exhibit the influence of streamflow, geomorphology, and vegetation interacting through time. These systems are geologically young and reflect such episodic events as floods, volcanic activity, and mass wasting. These events create active and often unstable stream systems. Precipitation is abundant and contributes to an extensive stream system.

Streams that originate in the area drain three mountain provinces: the Coast Ranges, Cascade Range, and Klamath Mountains. Although there are many similarities in habitat in each province, there are also differences in origin and characteristics that can influence responses to land use activities.

The Cascade Range is of Mesozoic origin, modified by volcanism and glaciers over the past 10 million years. Slopes and soils tend to be fairly stable. The Coast Ranges are composed primarily of sedimentary and igneous rock. The sedimentary material in particular is highly subject to erosion and both surface and mass erosion are common on steep slopes. The Klamath Mountains are composed of largely pre-Tertiary marine sediments and volcanic materials, much of which are unstable and highly erodible.

Glacial and volcanic activity have been the principal factors of lake formation in the Cascade and northern Coast Ranges, but mass erosion events have accounted for many of the lakes in the middle and southern portion of the Coast Range. All landforms in the area are dotted with large and small reservoirs that have been constructed on most major rivers during this century.

Plant Communities and Drainage Systems

The most productive habitats for salmonids in western Oregon and Washington are located in temperate and high temperate coniferous forests. Drainage systems and salmonid habitats in these plant communities have developed in close association with old-growth coniferous forest stands. The dense vegetative canopies tend to shield streams from solar radiation and keep waters cool, while litterfall provides a source of nutrients and energy for the stream ecosystem. Large organic debris from the old-growth forests has a major influence on the physical characteristics of the small stream systems, which in aggregate provide the majority of salmonid spawning and rearing habitat.

Historically, streams contained massive accumulations of woody debris that created a complex aquatic environment of riffles, pools, runs, glides, and side channels. Substrates ranged from silt to clean gravels to boulders. Large woody debris and boulders provided roughness and stability to stream channels, retarded the rate of downstream flow at all seasons, and generally made stream systems (especially small systems) inefficient routes for flowing water. These channel constrictions provided diverse and productive salmonid habitats in all seasons. In winter they caused frequent flood-plain flooding, developed a complex network of channels, acted as dissipators of stream energy, and tended to mitigate the height of downstream flood peaks by slowing streamflow. In summer they provided cover and a complex array of depths, velocities, and substrates for rearing salmonids. These species developed in harmony with the complex habitats and frequent flooding of forested streams that resulted from this accumulation of large woody debris. Historically, high levels of salmonid productivity occurred in such habitats.

Stream Orders

In our discussion, streams will be referred to by "order" acccording to the system of Strahler (1957). Under this system, the initial undivided stream channels are designated as first-order streams. Two first-order streams combine to form a second-order stream. A third-order stream is formed by the union of two second-order streams, and so forth (fig.1).

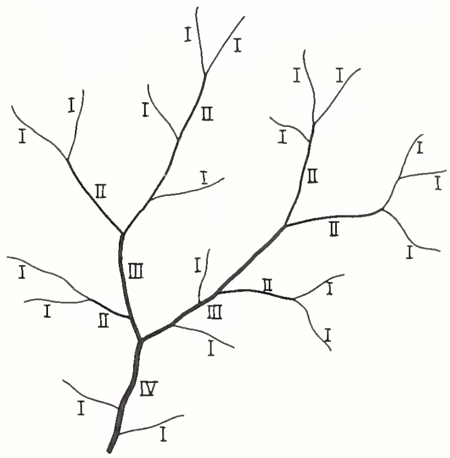


Figure 1.—Stream order (after Strahler 1957) in a typical watershed. The majority of stream mileage is in first- and second-order tributaries in all watersheds of western Oregon and Washington.

Leopold et al. (1964) estimated that 85 percent of the streams in the United States are first- and second-order. All streams, therefore, are dependent on small headwater channels that are vitally important contributors to the type and quality of fish habitat downstream.

Flow in aquatic systems begins in first-order streams that receive initial runoff from precipitation. Because of the limited ground water reservoir for these streams, many have only ephemeral or intermittent flow (fig. 2). Others receive enough ground water discharge to maintain small flows during dry periods. The same is true for many second-order streams.

First- and second-order streams are actively and directly influenced by the geomorphology, soils, and vegetation in the channel. Large woody debris is common and may cover up to 50 percent of the channel area. The vegetative canopy in the undisturbed state is often complete and provides continuous shading. Energy of water flowing in the channel is continually dissipated by

Figure 2.—Small first-order headwater streams rarely sustain perennial flow or salmonid populations.

Figure 3.—Third-order streams are of moderate size but often support large salmonid populations.

woody material and vegetation, retarding erosion and leading to deposition of organic and inorganic materials. Average gradient of these streams often exceeds 10 percent, but the channels usually have a stairstep configuration of flat reaches connected by riffles and low falls. Although first- and second-order streams are often intermittent or dry in summer, during periods of high flow these streams can transport large amounts of sediment and woody debris to downstream areas.

Third- and fourth-order streams are usually perennial, receive flow from first- and second-order tributaries, and generally have gradients below 5 percent, but stretches of rapids or falls are not unusual. Woody debris usually covers less than 25 percent of the channel (fig. 3). The streams have considerable energy at high flow, and woody material is often either flushed from the system or deposited in aggregations or jams.

The vegetative canopy over third- and fourth-order streams is variable and may range from completely closed to open. These streams are capable of transporting large amounts of sediments, but depostion often occurs around channel obstructions or in sinuous areas. Sediment deposition also occurs in other areas of low velocity, such as accretion bars, estuaries, and in the flood plain.

In fifth-order and larger streams, which include the larger rivers, the direct influence of riparian areas moderates, but it is still important (fig. 4). Heavy canopies of large, old-growth trees provide some shade; vegetated riparian zones tend to keep the main channel confined; and the largest boles of down trees may remain for some time along the stream, providing important summer and winter habitat for salmonids. Flood plains of the larger streams are complex and contain an array of side channels, overflow channels, and isolated pools. The side channels are often created and maintained by large woody debris (Sedell et al. 1981). The influence of the riparian area on water temperature, however, is minimal. Gradient tends to be low in the large streams, usually less than 1 percent, but rapids and falls may still be present. Deposits of alluvial material and woody debris may occur in quiet areas, but accumulations are subject to flushing and rearrangement during high flows. Water quality in these streams is determined by the quality of cumulative inflow from upstream tributaries, out-of-channel water uses, return flows, and pollutants. Some general characteristics of aquatic habitats are listed in table 1.

Figure 4.—Mainstem rivers of the Pacific Northwest are usually fifth-order or larger and provide spawning, rearing, and migration habitat for salmonids.

Table 1—Some general characteristics of aquatic habitat of western Oregon and Washington

Habitat factor	First- and second-order stream	Third- and fourth-order stream	Fifth-order or larger stream	Lakes	Cold-water reservoir	Warm-water reservoir
Water cycles	Winter-spring peak; may be ephemeral or intermittent	Winter-spring peak; Aug.-Sept. low flow; perennial; wide flow range	Winter-spring peak; moderate flow range; low flow Aug.-Sept.	Some seasonal fluctuation, depending on lake and water source	Depends on withdrawal cycles	Depends on withdrawal cycles
Water quality	Largely determined by inflow; highly responsive to local conditions	Moderately influenced by local conditions and by inflow	Largely determined by upstream conditions, out-of-channel uses, and pollution	Mostly oligotrophic; stratification common in most lakes	Oligotrophic to eutrophic; stratified; cool temperatures	Oligotrophic to eutrophic; stratified; warm temperatures
Cover	Canopy usually complete in undisturbed condition	Canopy averages 75 percent; may range from open to completely closed	Limited shading, amount depending more on size of channel than on vegetation of riparian zone	Limited	Largely absent	Largely absent
Reproduction habitat	Seasonally usable by fish moving upstream	Used by resident fish and upstream migrants	Several types present; used by residents and migrants	Limited to abundant; tributaries often used; most used by introduced species	Upriver access available; in reservoir, limited by drawdown schedule	Upriver access available; in reservoir, limited by drawdown schedule
Rearing area	Limited; used seasonally by recent hatchlings	Limited to younger age classes; used on annual basis; overwintering and oversummering common	Abundant, several types and locations; overwintering and oversummering common	Abundant for adapted species	Available to adapted species; amount depends on drawdown schedule	Available to adapted species; amount depends on drawdown schedule
Food	Large percentage falls from surrounding areas; instream production low	Partially drift from upstream, partially instream production; some insect drop from canopy	Mostly produced instream, some downstream drift	Limited in most; plankton, on cyclic basis; benthos	Planktonic on cyclic basis; benthos; inflow	Planktonic on cyclic basis; benthos; inflow
Structure (large woody debris, boulders)	Common, may be over 50 percent; random; important for cover, diversity	25 percent of channel; tendency to cluster; important for cover, diversity	10 percent; scattered; creates winter off-channel habitat	Limited; depends on shoreline development and depth	Limited; depends on shoreline development and drawdown schedule	Limited; depends on shoreline development and drawdown schedule
Fish use	Cutthroat trout; adult coho and steelhead spawners	Cutthroat trout, squawfish, suckers, sculpins, coho, chinook, steelhead; coastal areas: chums and pinks	Cutthroat uncommon; all salmon, steelhead; all native species; many introduced species including nongame warm-water fish species	Native salmonids, especially where tributaries are available for reproduction; lacustrine-adapted, introduced species	Native fishes, adaptable introduced species	Favored by lacustrine-adapted, introduced species

Key Streams for Salmonid Production

Because small streams (first- to third-order) make up a high percentage of the total stream mileage in western Oregon and Washington, and because aggregate flow from small headwater streams is so important to the quality of water and fish habitat downstream, proper management of small streams and their associated watersheds is an essential key to compatible management of forest and fishery resources.

Salmonids of the coastal Northwest utilize a wide variety of streams ranging in size from headwater tributaries to the mainstem Columbia River. But a preponderance of spawning and rearing by coho salmon, steelhead, and cutthroat trout in forested watersheds take place in second-, third-, and fourth-order streams (table 2). Reproduction in small streams, and even some first-order streams with ephemeral flow, often is adequate to seed larger waters many miles downstream with salmonid fry (Everest 1973).

Table 2—Percent of stream mileage by stream order, and by anadromous fish use, in a typical coastal watershed, East Fork Winchuck River, Oregon[1/]

Stream order	Miles	Percent total miles	Percent anadromous fish use
I	290	48.4	8.6
II	165	27.5	48.8
III	110	18.4	32.5
IV	34	5.7	10.1
Total	599	100.0	100.0

[1/] From Everest and Harr 1982

Although first-order streams are vital to the quality of salmonid habitat downstream, their importance often is overlooked because intermittent flows prevent them from contributing any significant onsite production. The channels of these streams act as viaducts that carry water, sediment, nutrients, and woody debris from upper portions of the watershed to larger tributaries downstream. The rate at which these organic and inorganic inputs are transported downstream, and the time of transportation, both of which are readily influenced by forest management, determine to a large extent the quality of downstream habitat for salmonids.

Although small streams are responsible for a significant proportion of anadromous fish production in a river system and for maintaining the quality of habitat downstream, they are also the streams most easily altered by human activities. Small streams are intimately associated with their riparian zones and are highly responsive to alterations in riparian vegetation and the adjacent watershed. Vegetative crown cover often is complete in first- through third-order streams, and the streams depend mostly on litterfall for organic energy inputs. Therefore, manipulation of canopy or streambank vegetation, or upslope activities such as road development and timber harvest, create immediate changes in stream equilibrium. Removal of the canopy, or a portion of it, results in direct solar heating of surface waters and a shift from a detrital energy base to a solar base. Although logging often causes short-term increases in woody debris added to the channels, at the same time it reduces the source of large organic debris. The quantity of instream debris has been observed to drop after logging (Osborn 1980). Road development, clearcutting, site preparation, and other activities upslope may rapidly increase sediment transport to the channel. Such changes in habitat, singly or in combination, can have a serious negative impact on production of anadromous salmonids.

Large streams are not as easily influenced by changes in their immediate environment as are smaller streams. Wide streams with large volumes of flow are usually open to direct sunlight but are more resistant to solar heating, and because of their greater depth and volume, can transport more sediment and woody debris. Logging along large streams can affect the quality of fish habitat in the channel, but much less than similar activities along small streams. Onsite effects, however, can be severe if side channels are diked or filled, thus eliminating summer and winter habitat for juvenile salmonids. The cumulative effects of logging along many small streams in a watershed, however, can eventually cause temperature and sediment increases and loss of large woody debris sufficient to reduce or eliminate salmonid production in larger downstream waters.

Critical summer rearing and overwintering habitats along the edges and side channels of larger streams are extremely sensitive to resource management activities. As a rule, the larger the stream, the greater relative role the flood plain plays in the fisheries. Productive side channels of larger streams (Sedell et al. 1981) provide valuable and heavily utilized summer rearing habitat. In winter these habitats are well buffered from floods and provide secure habitats for juvenile salmonids and their aquatic insect food resource (Peterson 1980).

Salmonid Species

The salmonid fauna of western Oregon and Washington is diverse and abundant. Sixteen species representing five genera of the family Salmonidae are present (table 3). A high percentage of the native species are anadromous (searun) and provide major sport and commercial fisheries (fig. 5). In addition to the native salmonid fauna, a few resident exotic species have been introduced (table 3). The salmonids are well adapted to the cold streams and lakes of the Northwest, and their migratory abilities and salinity tolerances have permitted colonization of nearly all accessible waters.

Anadromous species have developed complex life cycles that utilize freshwater streams, some lakes, and intertidal sloughs for reproduction; freshwater streams and lakes for juvenile rearing of some species; and estuaries and the ocean for juvenile rearing of others. All anadromous species normally rear to adulthood in marine waters. The variations in life-history patterns can be divided into several categories (table 4), which vary in seasonal occurrence for adults and juveniles in freshwater (table 5).

Resident species generally have simpler life-histories that are fulfilled entirely in freshwater. Some species make short migrations between streams and lakes, or within streams, for reproduction or rearing. Introduced species and their approximate ranges are shown in figure 6.

Table 3—Common and scientific names, and origin, of the salmonids of western Oregon and Washington

Common name	Scientific name	Origin
Pink salmon	Oncorhynchus gorbuscha (Walbaum)	Native
Chum salmon	Oncorhynchus keta (Walbaum)	Native
Coho salmon	Oncorhynchus kisutch (Walbaum)	Native
Sockeye salmon (kokanee)	Oncorhynchus nerka (Walbaum)	Native
Chinook salmon	Oncorhynchus tshawytscha (Walbaum)	Native
Pygmy whitefish	Prosopium coulteri (Eigenmann and Eigenmann)	Native
Mountain whitefish	Prosopium williamsoni (Girard)	Native
Golden trout	Salmo aguabonita Jordan	Introduced
Cutthroat trout (searun)	Salmo clarki Richardson	Native
Rainbow trout (steelhead)	Salmo gairdneri Richardson	Native
Brown trout	Salmo trutta Linnaeus	Introduced
Bull trout	Salvelinus confluentus (Suckley)	Native
Brook trout	Salvelinus fontinalis (Mitchill)	Introduced
Dolly Varden	Salvelinus malma (Walbaum)	Native
Lake trout	Salvelinus namaycush (Walbaum)	Introduced
Arctic grayling	Thymallus arcticus (Pallas)	Introduced

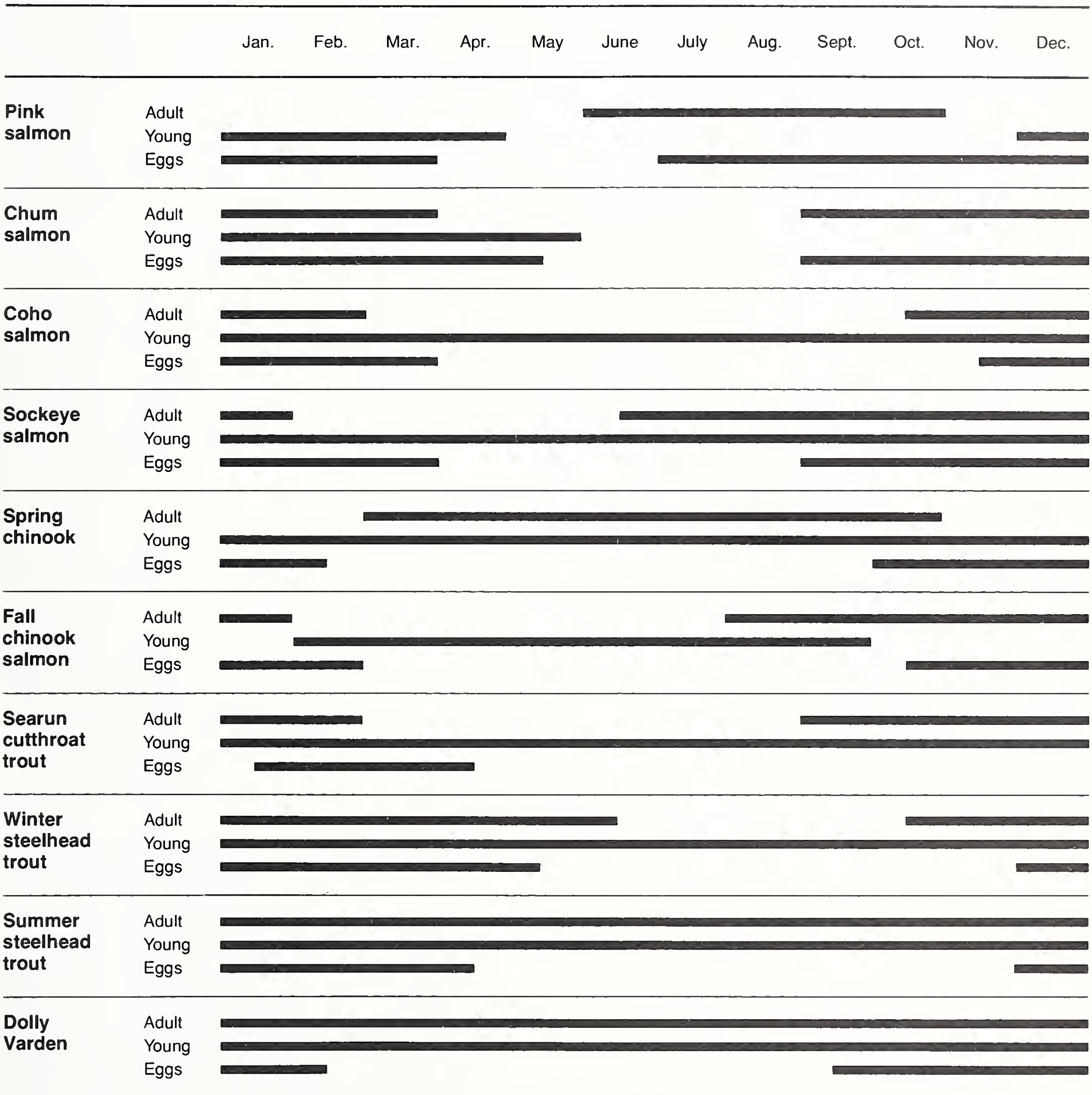
Figure 5.—Anadromous salmonids support intense commercial fisheries along the north Pacific coast.

Table 4—Variations in life history of salmonids

Species/race	Life history [1]	Reproduces in:		Rears in:			
		Lakes	Streams	Lakes	Streams	Estuaries	Ocean
Pink Salmon	Anadromous		X		X	X	X
	Anadromous		X				X
Chum Salmon	Anadromous		X		X	X	X
	Anadromous		X		X		X
	Anadromous		X				X
Coho salmon	Anadromous		X		X	X	X
	Anadromous		X		X		X
Sockeye salmon	Anadromous		X	X			X
	Anadromous	X		X			X
Sockeye salmon (kokanee)	Resident		X	X			
Chinook salmon (spring)	Anadromous		X		X	X	X
	Anadromous		X		X		X
Chinook salmon (fall)	Anadromous		X		X	X	X
	Anadromous		X		X		X
Pygmy whitefish	Resident	X		X			
Mountain whitefish	Resident		X		X		
Golden trout	Resident		X		X		
	Resident		X	X			
Cutthroat trout	Resident		X		X		
	Resident		X	X			
Cutthroat trout (searun)	Anadromous		X		X	X	X
	Anadromous		X		X		X
Rainbow trout	Resident		X		X		
	Resident		X	X			
Rainbow trout (steelhead)	Anadromous		X		X		X
Brown trout	Resident		X		X		
	Resident		X	X			
Bull trout	Resident		X		X		
	Resident		X	X			
Brook trout	Resident	X		X			
	Resident		X		X		
	Resident		X	X			
Dolly Varden	Anadromous		X		X	X	X
	Anadromous		X		X		X
	Anadromous		X	X			X
Lake trout	Resident	X		X			
Artic grayling	Resident		X		X		
	Resident		X	X			

[1] Some species have several races with different life history patterns.

Table 5—Seasonal occurrence of adult and juvenile (eggs in gravel and young) anadromous salmonids in freshwaters of western Oregon and Washington



Other Species

More than 50 species of nonsalmonid fishes also inhabit western Oregon and Washington. Most of the species are nonmigratory, but some are anadromous, and many have been introduced. A summary of the major groups of nonsalmonids is included in appendix 9, and life histories and habitat preferences of each species or group are listed in appendix 10. Because the distribution and habitat requirements of salmonids and nonsalmonids overlap, the assumption is that if optimum habitat for salmonids is maintained, generally the requirements for native nonsalmonids will also be fulfilled.

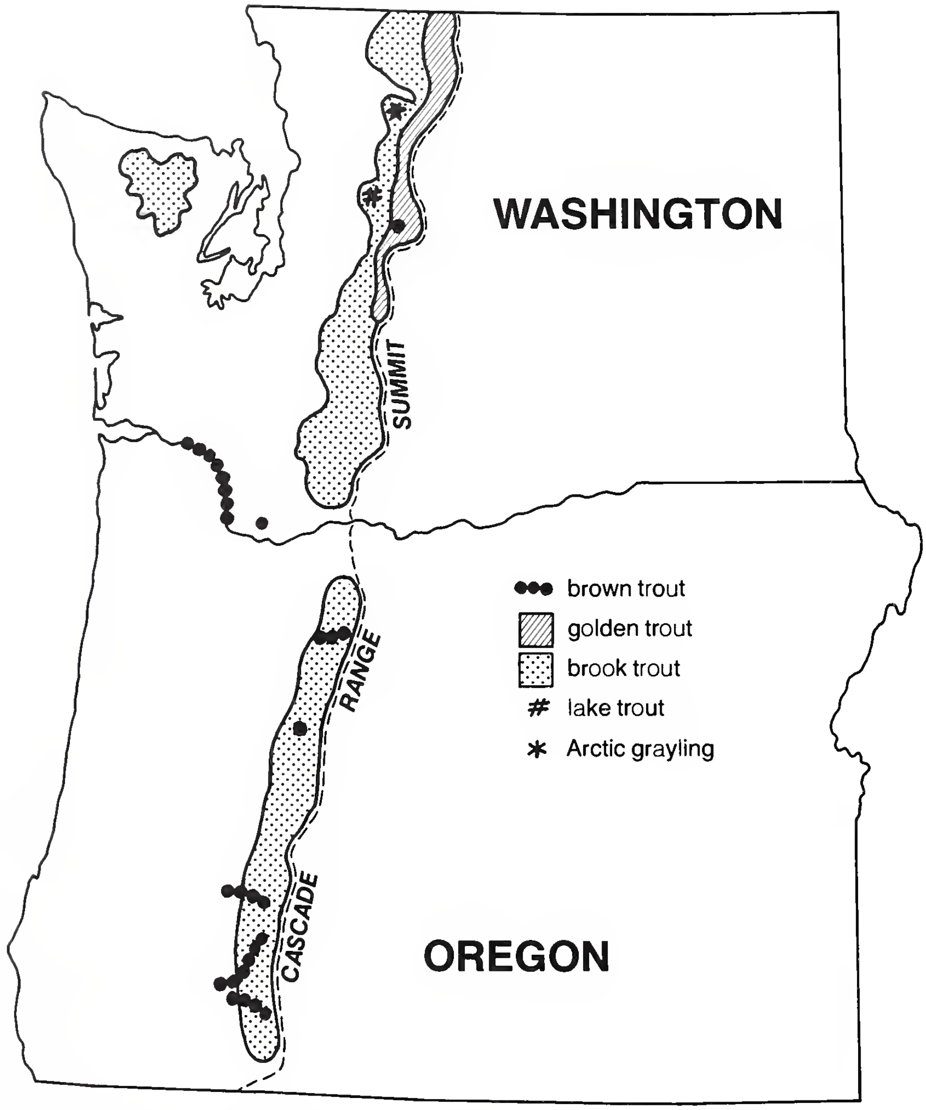


Figure 6.—Approximate distribution of introduced salmonids in western Oregon and Washington.

Salmonid Habitat Requirements

Anadromous Salmonids

Anadromous salmonids use both freshwater and marine environments and have rather exacting requirements. All species reproduce in freshwater or intertidal areas, and most rear there for varying periods of time before migrating to sea where they mature. Requirements for freshwater habitat vary slightly, but all species have some in common. For optimum production, all species require: cool, flowing waters; free migratory access to and from the sea; clean gravel substrate for reproduction; water of low-sediment content during the growing season (for sight feeding); high levels of dissolved-oxygen content in streams, lakes, and intragravel environment; sufficient instream cover; and invertebrate organisms for food. Each species has slightly different preferences and these are presented in detail in the following pages (also see Reiser and Bjornn 1979). Substantial deviations from optimum conditions can markedly reduce production.

Migration

Habitat for the successful migration of adult and juvenile anadromous salmonids depends on water depth, velocity, temperature, turbidity, and dissolved oxygen (fig. 7). Favorable combinations of these parameters can result in the successful migration of adult and juvenile anadromous salmonids. Physical conditions such as natural or constructed barriers, or water-quality problems caused by chemical pollutants, excessive temperature changes, or sediment, can halt or delay migration.

Upstream Migration of Adults Some observations on acceptable water temperatures, minimum depths, and maximum velocities for the successful upstream migration of adult salmon and steelhead trout are presented in table 6. Fish might not successfully migrate long distances at the depths and velocities listed. Also, migratory ability varies with size; larger fish can negotiate swifter currents but require greater depths than smaller fish. In addition, the dissolved-oxygen concentration must be near saturation for adults to sustain swimming speeds during their migration. Davis et al. (1963) reported that the maximum sustained swimming speed of adult coho salmon at temperatures of 50° to 68°F

Figure 7.—Most anadromous salmonids are capable of negotiating substantial rapids and falls during spawning migrations.

was adversely affected when oxygen was reduced from air-saturation levels. Reiser and Bjornn (1979) indicate that migrating adult salmonids need dissolved oxygen concentrations of at least 80 percent of saturation. Low dissolved oxygen, however, rarely affects migration of salmonids in flowing streams because water is constantly aerated by riffles.

Excessive turbidities can stop or delay upstream migrating salmonids (Bell 1973). Bell cited a study of the effects of a natural slide in the Chilcotin River in British Columbia that indicated salmonid fish will not migrate into streams where the silt content is above 4,000 ppm.

Physical barriers such as debris dams, power and water diversion dams, waterfalls, and culverts can physically stop or delay migrating salmonids. Height alone can stop fish passage, but these barriers may also impede movement in other ways such as the creation of excess water velocities, the reduction or alteration of streamflows, or through development of adverse water-quality conditions. It is important, however, to observe apparent barriers over a range of stream flow conditions before drawing conclusions about their impact on fish passage. What proves to be a barrier under some flow conditions may not be under others.

Water velocities of 10 to 13 feet/second approach the upper swimming ability of salmon and steelhead and could retard upstream migration (Reiser and Bjornn 1979). The swimming performance of migrating fish usually is described in terms of: cruising speed—the speed a fish can swim for an extended period (hours); sustained speed—the speed a

Table 6—Water temperature, minimum depth, and maximum velocity criteria for successful upstream migration of adult salmon and trout

Species of fish	Temperature range 1/	Minimum depth 2/	Maximum velocity 2/
	°Fahrenheit	Feet	Feet/second
Pink salmon	45-60	0.59 3/	7.0 3/
Chum salmon	47-60	0.59	8.0
Coho salmon	45-60	0.59	8.0
Sockeye salmon	45-60	0.59 3/	7.0 1/
Spring chinook salmon	38-56	0.79	8.0
Summer chinook salmon	57-68	0.79	8.0
Fall chinook salmon	51-67	0.79	8.0
Steelhead trout		0.59	8.0

1/ From Bell (1973), converted to English units.
2/ From Thompson (1972), converted to English units.
3/ Based on fish size.

fish can maintain for a period of several minutes; and darting speed—the speed a fish can swim for a few seconds. Table 7 indicates the swimming speeds of average-sized adult salmonids (Bell 1973). Any management-induced changes in stream channels that create water velocities exceeding the minimums listed under sustained speed in table 8, or localized velocities exceeding those listed under darting speed, could stop or delay migrations of adult salmonids.

Table 7—Swimming abilities of average-sized adult salmonids [1]

Species of fish	Cruising speed	Sustained speed	Darting speed
	-Feet per second-		
Coho salmon	0.3.4	3.4-10.6	10.6-21.5
Sockeye salmon	0-3.2	3.2-10.2	10.2-20.6
Chinook salmon	0-3.4	3.4-10.8	10.8-22.4
Steelhead trout	0-4.6	4.6-13.7	13.7-26.5

[1] From Bell (1973), converted to English units.

Reduced water flows resulting from storage at dams and withdrawal for domestic, municipal, or irrigation use can result in delayed migrations of adults because required minimum water depths are not maintained (table 6). Poor quality water released from impoundments or insufficient attraction flow at fish ladders may also delay or stop migration. Conversely, properly timed water releases from impoundments can be used to induce migration and manage fish passage through a river system below a dam.

Migrating adults can negotiate many barriers if sufficient flow and water depth occurs. Laboratory studies indicate that ideal leaping conditions for fish can be obtained when the ratio of the height of a falls to the depth of a pool is 1:1.25, respectively. Stuart (1962) observed salmon jumping 6.5 to 10 feet, but any barrier exceeding 5 feet might impede migration at some streamflows. This is especially true for chum salmon, which have poor jumping ability.

Migration of Juveniles Juvenile salmonids (smolts) migrating downstream to the sea in the spring encounter varying water quality as well as physical barriers such as dams. Water quality is usually satisfactory during downstream migratory periods, however, because of the quantity and quality of water in the rivers and streams during the spring. Acceptable water temperatures range from about 45°F to 65°F, with a preference of about 58°F. Dissolved oxygen should be near saturation—a criterion that is usually met in free flowing streams. Water temperatures in the preferred range (table 8) and dissolved oxygen concentrations at or near saturation create ideal conditions for migration of juveniles. Where low dissolved-oxygen concentrations and high water temperatures do occur, they could hamper the swimming ability of juveniles and cause serious problems during their downstream migration. A 50 percent reduction in the swimming capability of salmonids is known to occur at upper and lower temperature limits (Bell 1973).

Turbid water can cause gill irritation to juvenile salmonids during downstream migration. Experiments indicate that fish can survive in high concentrations of suspended materials for short periods, but prolonged exposure to abrasive materials results in thickening of respiratory epithelial cells in most species which interferes with respiration (Bell 1973, Sigler and Bjornn 1980). Salmonids are apparently more susceptible to stress from suspended sediment in spring and summer than in fall and winter (Noggle 1978, Redding and Schreck 1980).

Free upstream access for juvenile salmonids should also be maintained in small streams to take advantage of short-term rearing opportunities . Young salmonids often make short migrations from mainstem rearing or spawning areas into small tributaries, even some that become intermittent in summer. Such migrations usually occur on the first fall freshets, but upstream dispersion of salmonid fry also occurs in late winter and spring. Juvenile salmonids are less effective at passing barriers than adults and might be stopped by barriers as low as 2 feet high, or water velocity exceeding 3 feet/second. Improperly installed culverts on small streams often block upstream access for juvenile salmonids even though they allow passage of adults.

Table 8—Preferred temperatures for various juvenile salmonids (data developed from laboratory studies)[1]

Species	Preferred temperature range
	°Fahrenheit
Pink salmon	42-58
Chum salmon	52-58
Coho salmon	53-58
Sockeye salmon	52-58
Chinook salmon	45-58
Cutthroat trout	49-55

[1] From Bell (1973), converted from Celsius to Fahrenheit.

Figure 8.—Salmonids require clean gravels and high quality water for spawning.

Table 9—Spawning requirements for anadromous salmonids (all data standardized in English units)

Species	Water depth	Water velocity	Substrate size	Preferred temperature
	Feet	Feet/second	Inches	°Fahrenheit
Pink salmon	>0.5 [6]	0.7-3.3 [6]	0.5-4 [3]	45-55 [3]
Chum salmon	>0.6 [4]	1.5-3.3 [4]	0.5-4 [3]	45-55 [3]
Coho salmon	>0.6 [1]	1.0-3.0 [1]	0.6-5 [2]	45-60 [3]
Sockeye salmon	>0.5 [5]	0.7-3.3 [5]	0.5-4 [3]	51-54 [3]
Chinook salmon	>0.8 [1]	1.0-3.0 [1]	0.5-4 [3]	42-57 [3]
Cutthroat trout	>0.2 [7]	0.4-2.4 [7]	0.2-4 [7]	43-63 [3]
Steelhead trout	>0.8 [4]	1.3-3.0 [4]	0.2-4 [7]	39-49 [3]

[1] Thompson (1972).
[2] Briggs (1953); Phillips (1964).
[3] Bell (1973).
[4] Smith (1973).
[5] Reiser and Bjornn (1979)
[6] Collings et al. (1970).
[7] Hunter (1973).

Spawning

In addition to depth, velocity, substrate, and temperature, cover is an important element of the habitat for spawning salmonids (fig. 8). Cover is difficult to quantify—it can be deep water, submerged objects, overhanging vegetation, or undercut banks. Cover may be a factor in the selection or abandonment of spawning sites. Some spawning requirements of anadromous salmonids inhabiting west side streams have been identified (table 9).

Rearing

The availability of favorable rearing areas for a given salmonid species during summer is directly related to the volume of instream flow. In-stream flow provides the macrohabitat within which juvenile salmonids seek microhabitats with specific physical characteristics. The volume of flow in summer determines the carrying capacity of the stream for juvenile salmonids. Winter flow patterns coupled with the quantity of in-channel or off-channel refuges for wintering juveniles can also limit carrying capacity.

Physical microhabitat requirements for a given species of fish can be divided into a number of parameters: water quality, depth, velocity, cover, substrate, space, and availability of food (fig. 9). Preferences have been established for a

Figure 9.—Productive habitat for rearing salmonids contains adequate water quantity and quality, invertebrate food, cover, and a diversity of water depths and velocities and substrate materials.

number of salmonid species of various sizes (table 10). The table, although giving some indication of preferences for rearing habitat of young salmonids, should be used with caution because studies have not focused on the complexity of the interrelationship of the physical parameters with the size of fish and time of year. For example, salmonids generally seek out slower velocities during winter than those shown in table 10 (Bustard and Narver 1975).

Spatial requirements, food abundance, and cover are parameters that cannot be easily tabulated because they are interrelated. Chapman (1966) showed that spatial requirements for juvenile coho decreased as food supply and cover increased. Increased food supply reduces territorial behavior and spatial requirements. Increased cover provides visual isolation and reduces aggressive behavior. Similarly, Mason (1976) found that food, not space, was limiting coho during the summer but that coho survival in winter was limited by availability of habitat. Spatial, food, and cover requirements of salmonids are complicated by the fact that they change, both with time of year and size of fish (Chapman and Bjornn 1969).

The importance of cover has long been recognized in the ecology of salmonids. Cover can take many forms, including overhanging vegetation, deep water, surface turbulence, large rubble and boulders, undercut banks, and perhaps most important of all in forest streams, woody debris. Large woody debris not only provides a direct source of in-stream and overhead cover, but also functions as an in-stream scour agent to produce and maintain high quality pools, provide surface turbulence, sort substrate materials, and form undercut banks. Woody debris deposited in the flood plain and in off-channel habitat provides essential protective cover for juvenile salmonids during high winter flows (Bustard and Narver 1975, Sedell et al. 1981). Isolating cover requirements from other habitat needs is difficult, but cover of various forms is clearly vital to rearing salmonids. The importance of cover seems to be greatest in small streams where juveniles are most vulnerable to avian, terrestrial, and aquatic predators.

Table 10—Some rearing-habitat preferences recorded for juvenile anadromous salmonids (all data standardized in English units)

Species	Size (inches) or age (years)	Water depth	Water velocity	Substrate size
		Feet	Feet/second	Inches
Coho salmon	2/4 inches	>1.0 1/	1.0 1/	0.4 2/
Chinook salmon	0+ years	0.5-1.0 3/	0.5 3/	Silt 3/
	1+ years	>2.0 4/	0.2-1.3 4/	
Cutthroat trout	2-6 inches	>1.0 5/	0.5-1.0 5/	2-8 6/
	4/6 inches	>1.0 5/	1.5 5/	2-12 6/
	6-8 inches	>1.3 5/	0.5-2.0 5/	2-12 6/
	8 inches	>1.3 5/	0.5-2.0 5/	12 6/
Steelhead trout	2-4 inches	0.5-1.5 5/	1.5 5/	4-12 6/
	4-6 inches	>1.5 5/	0.5-2.0 5/	4-12 6/

1/ Nickelson and Reisenbichler (1977).
2/ Lister and Genoe (1970).
3/ Everest and Chapman (1972).
4/ Stuehrenberg (1975).
5/ Oregon Department of Fish and Wildlife (unpublished data).
6/ Hanson (1977).

Resident Salmonids

General habitat requirements of resident salmonids are similar to those of juvenile anadromous salmonids, except that migratory access usually is less important for resident stocks. Optimum habitat has not been fully defined for all life stages of resident species, but a summary of known optimum conditions for spawning and rearing is included below.

Most adult resident fish are under 16 inches in length, although some, especially those reared in lakes, might rival anadromous species for size.

Resident salmonids often make substantial movements within streams, or from lakes to streams to reproduce. Consequently, maintaining free migratory access in streams is important even where resident forms are the only fish species present.

Spawning

Resident salmonids select spawning sites on gravelly riffles just as anadromous adults do, but generally seek shallower, slower water, and gravels of smaller diameter because of their smaller size (table 11). An exception is the lake trout that spawns in deep, cold lakes.

Rearing

Rearing requirements and preferences of resident salmonids are not well documented, but some studies have indicated that they are generally similar to those of juvenile anadromous salmonids (table 12).

Table 11—Some spawning preferences of resident salmonids (all data standardized in English units)

Species	Water depth	Water velocity	Substrate size	Water temperature
	Feet	Feet/second	Inches	°Fahrenheit
Kokanee	0.2[3]	0.4-2.4[1] [3]	0.0-3.0[2]	44-54[1]
Mountain whitefish	0.4[1]	—	0.0-6.0[2]	32-42[1]
Cutthroat trout	0.2-0.9[1]	0.35-1.3[1]	0.25-2.0[2]	40-55[1]
Rainbow trout	0.7-1.1[1]	1.60-3.0[3]	0.25-2.0[2]	40-55[1]
Brown trout	0.8[3]	0.67-2.2[3]	0.25-3.0[2]	45-55[1]
Brook trout	0.3[3]	0.03-1.4[3]	0.25-3.0[2]	35-50[1]
Dolly Varden	0.7-1.4[1]	1.13-2.2[1]	0.0-6.0[2]	46[2]
Artic grayling	0.4[1]	—	0.0-6.0[2]	40-52[1]

[1] Hunter (1973).
[2] Scott and Crossman (1973).
[3] Smith (1973).

Table 12—Some rearing-habitat preferences of juvenile resident salmonids (all data standardized in English units)

Species	Size (inches) or age (years)	Water depth	Water velocity	Substrate size	Water temperature
		Feet	Feet/second	Inches	°Fahrenheit
Kokanee Lake rearing	—	—	—	4[2]	—
Cutthroat trout	1 year	1.7[1]	0.3[1]	2-8[1]	50[3]
	2 years	1.8[1]	0.5[1]	2-12[illegible]	—
	3 years	1.9[1]	0.8[1]	2-12[1]	—
	4 years	1.8[1]	0.5[1]	12[1]	—
Rainbow trout	2-4 inches	0.5-1.5[4]	1.5[4]	4-12[1]	70[2]
	4-6 inches	1.5[4]	0.5-2.0[4]	4-12[1]	—
Brook trout	—	—	—	—	55[2]

[1] Hanson (1977).
[2] Hunter (1973).
[3] Scott and Crossman (1973).
[4] Oregon Department of Fish and Wildlife (unpublished data).

Habitat Use in Time and Space

Temporal and spatial use of aquatic habitat by anadromous and resident salmonids varies significantly by species and is related to subtle differences in fish morphology, physiology, and behavior. Preferences for different water depths and velocities, food organisms, cover, and substrate; as well as duration of residence in freshwater, and timing of migration and reproduction, tend to keep species ecologically isolated from one another in time or space in freshwater. Most streams contain several species of salmonids with slightly different life histories and habitat preferences. No two species can occupy the same ecological niche at the same time. Through natural selection, subtle differences in preferred habitat have developed that minimize competitive interactions between species and maximize production in a given habitat.

The variety of physical habitat available in freshwater streams is limited but nevertheless offers a suprising opportunity for ecological specialization of salmonid species. For example, adult pink and chum salmon usually make short spawning migrations into freshwater, and after emergence, fry immediately migrate to sea. They require minimum freshwater residence time for rearing. Sockeye salmon migrate to inlet or outlet streams of lakes where they spawn. After emergence, fry move into the lakes where they rear for up to 3 years. Adult coho salmon make upstream migrations of intermediate length and spawn primarily in small tributary streams, where juveniles rear in pools for about 1 year. Chinook salmon spawn in both large and small streams from tidewater to as far as 900 miles up major rivers; rearing occurs in pools of small, intermediate, and large streams. Fall chinook fry rear in freshwater for a few months; some spring and summer races rear in streams for about 1 year.

Steelhead are widely distributed in large and small streams, make long or short migrations, spawn in large to small streams, and rear for up to 3 years primarily in riffles. Cutthroat trout gener-

ally make short spawning migrations to small, steep tributaries where rearing generally occurs for 2 to 3 years. Dolly Varden make short or long migrations into small streams and rivers where fry rear primarily in pools for 1 to 3 years. Native resident species occur primarily in lakes and headwater streams not used by anadromous species. Each species uses slightly different resources at different times and places; consequently, a combination of species uses freshwater habitat more completely and produces more biomass than would any single species.

When several species of salmonids are present in a watershed and the habitat is fully seeded by spawning adults, both fish-population structure and biomass reach equilibrium with available food and quality of living space. Any substantial changes in habitat, either natural or as a result of human activities, shifts the equilibrium and causes changes in the structure of fish populations. Eventually a new equilibrium is established where total production of salmonids is either increased or decreased, or production of one species is favored over another.

Effects of Timber Management Activities and Roads on Salmonid Habitat

General Effects

Timber management activities and their associated road systems have three primary effects on salmonid habitat. These activities tend simultaneously to increase sediment and temperature in streams while reducing the source of large woody debris—the primary structural component of habitat in small streams. Other less important effects include changes in water chemistry resulting from timber cutting, burning, or use of forest chemicals, and increased biochemical oxygen demand (BOD) resulting from introduction of fine organic debris to streams. Minor changes in streamflow also occur. A few studies have documented that these effects, singly or in combination, have resulted in a decrease in the standing crop of salmonids. Most studies, however, have only assessed the effects of timber management on habitat, rather than on salmonids, because assessing fish populations is a long-term, expensive operation. Consequently, the relation of habitat changes caused by logging to populations of juvenile salmonids needs further documentation.

Salmonids are able to tolerate some short-term habitat disturbances through natural compensatory mechanisms, such as high reproductive rates and a fairly broad scope of physiological and behavioral responses. Salmonid populations have always had to cope with short-term habitat disturbances, such as floods, sedimentation from landslides, scouring of stream substrates, and deposition of organic debris in streams. These have always occurred naturally, with varying frequencies and magnitudes, and may depress fish production in the short run.

The frequency of these events, however, is often accelerated by timber management activities and the construction and use of forest roads. Frequent occurrences continuing at a sustained level in intensively managed watersheds can produce cumulative effects that overtax the tolerance and adaptive and compensatory mechanisms of salmonids, and can be expected to cause long-term decreases in salmonid productivity.

These accelerated events by themselves probably would not completely eliminate salmonids from forested watersheds, even in a worst-case situation (Salo and Cederholm 1981). When the cumulative effects of logging activities on freshwater life-history stages are combined with an intensive harvest of fish stocks in both fresh and saltwater, however, and imposed over natural mortality rates of salmonids, the result can be severely lowered fish production. Considerable evidence indicates that the effects of logging, if conducted in compliance with current forest practice rules, are not sufficient to reduce adult salmonids below the level required for stock replacement, but when logging and fishery influences operate concurrently, numbers of adults can drop below the replacement level.

The greatest impact of timber harvest results from removal of the forest canopy adjacent to and within the riparian area This activity generally produces higher summer and lower winter water temperatures. It reduces bank stability, and at the same time removes the buffering effect of the riparian area, which can significantly reduce the amount of sediment entering the stream. In time it will also reduce or eliminate the recruitment of large organic debris, which in turn will result in less structural complexity of the stream. Not all of the impacts are detrimental, however. Increased light reaching the stream can result in a short-term increase in production of algae and greater densities of drifting invertebrates, which form the basic diet of fish.

Research has shown that both fauna and flora are often more abundant in sections of streams with open canopies than in forested sections (Aho 1976, Albrecht 1968, Erman et al. 1977, Gregory 1980, Hughs 1966, LeCren 1969, Lyford and Gregory 1975, Murphy and Hall 1980, Newbold et al. 1980, Thorup 1966). Removal of streamside vegetation in small streamside clearcuts during logging appears to increase aquatic production at the lower levels of the food chain. This results from increased light availability, which stimulates algal and periphyton production (Gregory 1980, Murphy and Hall 1980). On the other hand, many reports of logging impacts emphasize the destructive potential of accumulated sediment that adversely affects stream habitat (Cordone and Kelly 1961, Gibbons and Salo 1973, Iwamoto et al. 1978). An equally serious adverse impact results from the long-term loss of large woody debris. Thus,

logging may have two opposing localized effects: canopy removal tending to increase basic stream productivity, and sedimentation and loss of large woody debris tending to decrease productivity.

Murphy et al. (1981) studied effects of accumulated sediment on stream communities in different forest successional stages. They found that small, open, clearcut sections of streams exhibited greater density, biomass, or both of invertebrates and cutthroat trout than did shaded, forested sites regardless of sediment composition. They concluded that for small streams in the Cascade Range, changes in fish-food status and increased production of algae resulting from shade removal masked or overrode effects of sedimentation. Their data indicate that strong linkages exist between light levels reaching the stream, primary production, invertebrate production, and ultimately vertebrate production. Gregory (1980) found that periphyton production in small streams in a western Oregon study area was light limited. Chapman and Knudsen (1980) used similar arguments to suggest that fish production in some Puget Sound streams was indirectly light-limited.

Thus canopy removal in small blocks can have positive impacts on stream productivity, but cumulative effects of extensive cutting might cancel any potential benefits. Sediment and canopy removal both have adverse effects in the long run. Increases in sediment load may cause the stream to become wide, shallow, and unstable, often with a braided channel (Leopold et al. 1964). Filling of pools with sedimentary material reduces suitable habitat for trout (Bjornn et al. 1974) and damages spawning habitat. These effects of sediment are not usually observed in sites where large woody debris from logging and natural blowdown create a stairstep channel profile and form plunge pools downstream of debris accumulations (Keller and Swanson 1979, Meehan et al. 1977). Canopy removal and stream cleanup operations usually result in a substantial loss of large woody debris that might otherwise have mitigated the effects of sediment. Canopy removal rarely causes onsite increases in stream temperatures that are lethal to trout (Moring and Lantz 1975, Martin et al. 1981), but sublethal increases can indirectly affect survival, and cumulative effects can reduce the quantity and quality of rearing habitat in downstream waters.

Elevated temperatures can cause physiological stress, which in turn increases susceptibility to disease and predation, and decreases competitive ability of rearing juveniles. Equally important, elevated water temperatures can reduce juvenile growth rates, thus reducing the number of anadromous salmonids reaching smolt size, or reducing the size of smolts. Hatchery studies have shown that small smolts have lower survival rates than larger smolts.

Physical habitat for anadromous salmonids has been altered in the last two decades by a combination of increased sediments, channel sluice-outs, (fig. 10), and excessive debris removal (often mandated by fisheries agencies) related to timber management. The cumulative

Figure 10.—Mass erosion events can sluice stream channels to bedrock and reduce complexity and productivity for salmonids.

result has been a loss of large, high quality pools necessary for rearing juvenile salmonids and holding adult salmon before they spawn. The majority of these high quality pools in small streams are caused by large tree-sized debris. Also, the majority of high quality cover in small streams is provided by large organic debris. Overzealous cleaning of the channel, or failure to make provision for long-term recruitment of large organic debris after cutting, can turn a productive stream suitable for fish of a wide range of sizes and ages into a marginal stream suitable primarily for underyearling fish (Bisson and Sedell [in press]). Coho salmon and cutthroat trout habitat generally is reduced in this manner in exposed and cleaned streams. The loss of high-quality pools removes temperature refuges as well. Big pools, in both small streams and large rivers, tend to stratify thermally in summer, providing cool-water refuges in areas where cool surface water or ground water enters the stream and collects (Everest 1973).

Specific Effects

Migration

At certain times both adult and juvenile salmonids require unobstructed upstream or downstream access for migrations or dispersal. Timber management activities can affect these migrations and dispersal in several ways. Mass erosion events resulting from clearcutting or road construction can block upstream access for adult and juvenile salmonids for several years, and changes in water temperature and streamflow caused by timber harvest can cause temporary blocks to migration. Occasionally accumulations of logging slash cause migration blocks. The most serious potential threats to fish migration other than dams, however, are road culverts (fig. 11).

Figure 11.—Open bottom culverts and bridges make the best road crossing structures on salmonid streams.

Road culverts can stop spawning migrations of adult salmonids because of outfall barriers, excessive water velocities, insufficient flow through culverts, lack of resting or jump pools, or a combination of these factors (Yee and Roelofs 1980). Because dispersal of juvenile salmonids occurs upstream as well as downstream, and because juvenile fish are less able to negotiate culverts than adults, substantial seasonal rearing area can be lost because of impassable culverts on small streams. For example, in the Rogue River basin, large numbers of juvenile steelhead make short-term fall rearing migrations from the mainstem Rogue into seasonally intermittent tributaries (Everest 1973). The fish return to the mainstem late the following spring.

Landslides, slump earthflows, and debris torrents are common mass erosion events west of the Cascades and each has the potential to block fish migration routes. Debris torrents are the most common and widely distributed events, and often leave high jams of boulders and woody debris in stream channels. The rate of occurrence of debris torrents is closely related to timber harvest and the presence of roads (Swanson and Dyrness 1975).

Timber management activities can also negatively affect salmonid migrations by increasing water temperatures and reducing streamflow. Cumulative effects of removal of riparian vegetation on small streams can result in increased water temperatures in larger waters downstream and stop upstream movement of summer migrants such as summer steelhead and fall chinook salmon. Also, channel aggradation resulting from accelerated erosion can cause underground flow in small streams in summer as water flows subsurface through deep gravels. Such occurrences can temporarily halt instream movements of resident fish or juvenile anadromous salmonids and cause a significant increase in mortalities.

Spawning and Incubation

Successful reproduction by salmonids depends on an adequate supply of gravels with low sediment content. Quantity of gravel is usually not a limiting factor for salmonids, but several forest management activities—primarily construction, use, and maintenance of forest roads—can increase sediment in gravels, thus reducing the quality, which will ultimately affect reproductive success. The effect of sedimentation is more serious without the mitigating effects of large organic debris which, when present, tends to sort inorganic sediment and cause deposition of sand and silt at the stream margins and in the flood plains. Numerous studies have identified measurable decreases in intragravel survival of incubating eggs and alevins (newly hatched fry) as the proportion of fine sands and silts in the streambed increases. Cederholm and Salo (1979), Koski (1972), Phillips (1971), and Reiser and Bjornn (1979) all provide excellent summaries of the effects of sediment on salmonid intragravel survival.

Sediment in gravels can affect embryological development during incubation or prevent newly hatched fry from emerging. In relatively sediment-free spawning riffles (fig. 12), water is delivered freely through gravels of the redd (spawning nest), supplying a high concentration of dissolved oxygen to the eggs and alevins. Also, metabolic waste products are quickly swept away. But, as the interstitial spaces within the gravel become occluded with fine sediment, water flow through the redd is reduced and survival of eggs and alevins drops dramatically (fig. 13). Even if direct mortality does not occur, embryos that develop in the presence of low oxygen concentrations are smaller and less able to compete for resources than fry incubated at high oxygen levels (Doudoroff and Warren 1965).

Generally, as the density of roads in a watershed increases, the amount of suspended and intragravel fines also increases. Cederholm and Salo (1979) studied the relation of roads to streambed sediments for 8 years in the Clearwater River watershed of western Washington. They found that significant amounts (15 to 25 percent) of fine sediments (less than 0.85 mm diameter) accumulated in spawning gravels in heavily roaded tributary basins. When the roaded area exceeded 2 to 3 percent of the subbasin area, the accumulations

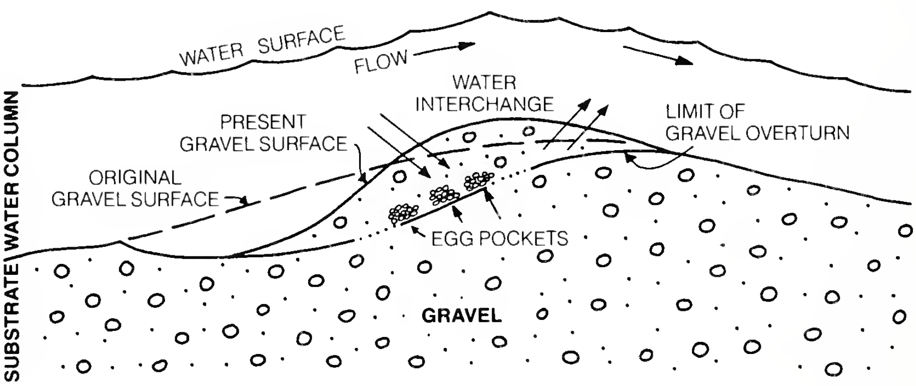


Figure 12.—Typical redd or nest of salmonid eggs, showing direction of interchange between surface water and water within the gravel bed (from Phillips 1971).

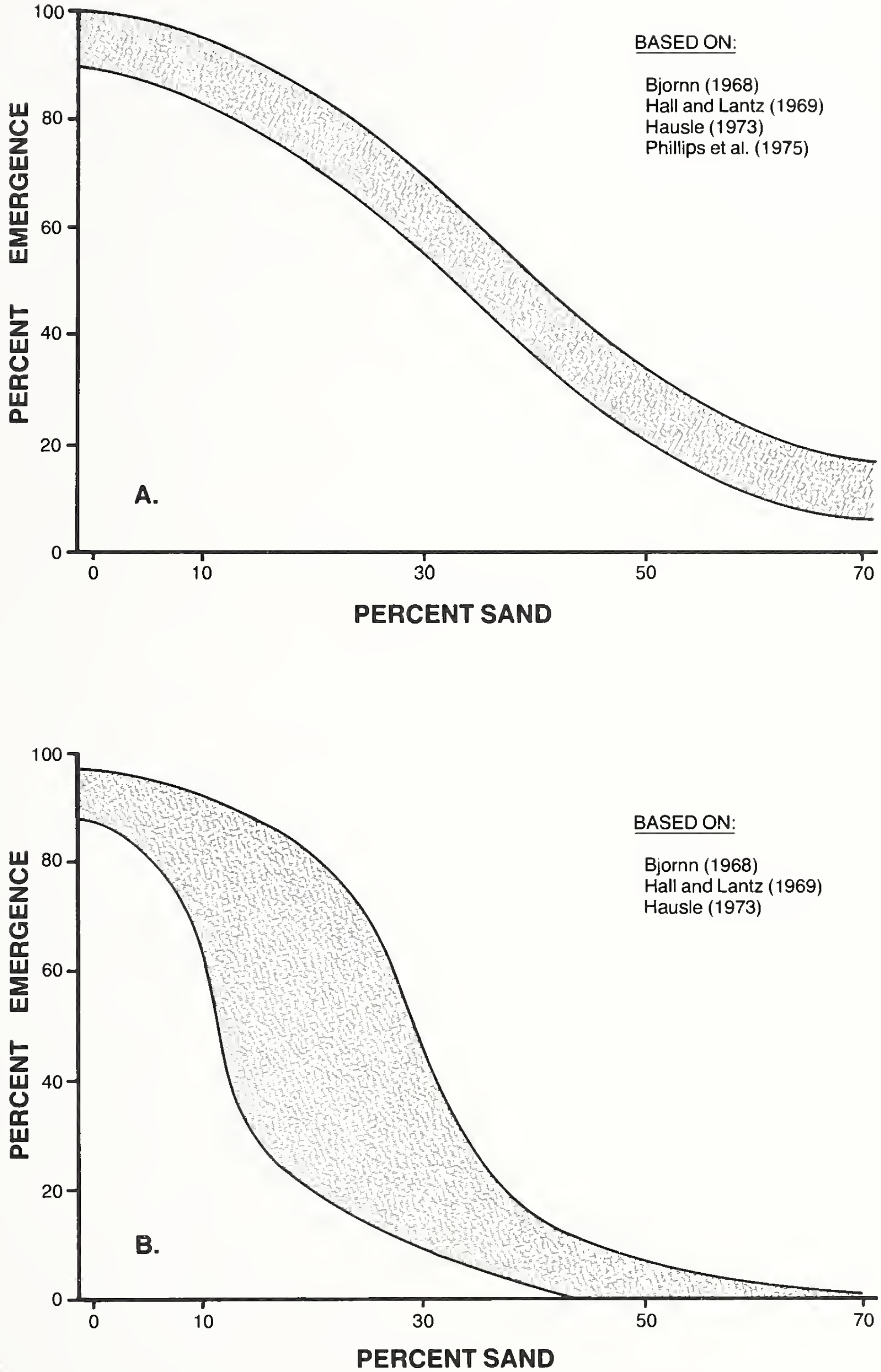


Figure 13.Composite of experimental inverse relation of percentage fine sands in gravels to survival to emergence of salmonids: A), alevins put into artificial redds; B), eggs deposited in redds (from Cederholm and Salo 1979).

were most pronounced (fig. 14). They further indicated that 60 percent of the road-related sediment production was caused by mass erosion events, and an additional 18 to 26 percent resulted from road-surface erosion (Cederholm et al. 1981). Reid (1981), studying road-surface erosion in the Clearwater drainage, showed that road segments used by more than 16 trucks daily contributed 130 times more sediment than roads not subjected to truck traffic, and 1,000 times more than from abandoned roads.

The principal mechanisms of mass soil failure in Pacific mountain ranges have been described by Fredriksen (1972), Larse (1971), Swanston (1970), and Swanston and Swanson (1976). Road construction was noted to accelerate mass soil movements by disturbing or destroying natural mechanical support on steep slopes and altering drainage patterns. Failures result from slope loading with excess sidecast material, from bank-cutting into the slope, and from inadequate slope drainage. In western Washington, channeling runoff from two or three small drainage areas through a single culvert frequently caused mass soil failures. Anderson (1971) summarized results of a Forest Service survey of 725 earth and debris slides in northern California after severe flooding in 1964-65. The majority of landslides were associated with roads or road construction. Similar results were reported by Swanson and Dyrness (1975), who observed that more than half of the debris torrents in a western Oregon study were associated with roads:

Land use	Percent slides
Undisturbed areas	22
Associated with logged areas	24
Associated with roads	54

In the Clearwater experiments, coho salmon and cutthroat trout eggs were planted in streams affected by landslides. The survival of cutthroat eggs was not significantly different in affected and unaffected areas, but survival of coho was significantly reduced in affected

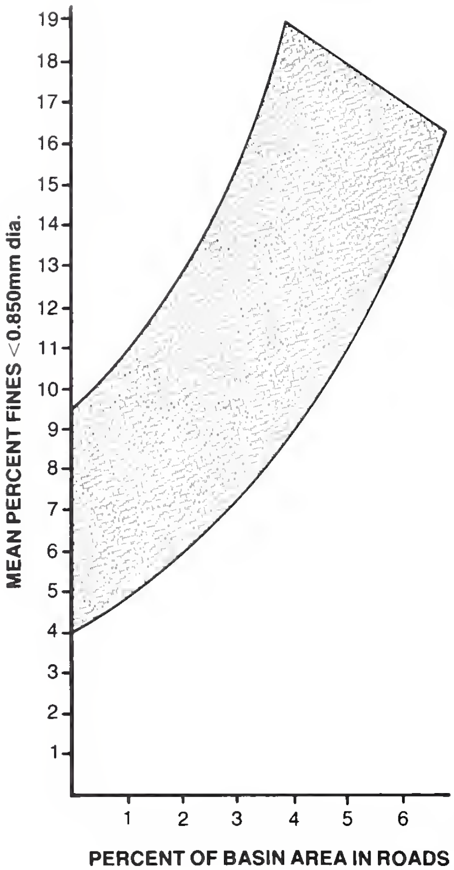


Figure 14.—Statistical relation of the percent of basin area in roads to the percent of fine material in the spawning gravels at the lower ends of 44 basins (from Cederholm and Salo 1979, and Cederholm, 1982).

areas (Cederholm and Salo 1979). Everest and Meehan (1981), in studying the impact of a debris torrent on a small Oregon coastal stream, found 12 percent fine sediment (less than 1 mm diameter) in the gravel above the torrent, as opposed to 23 percent in the area affected by the torrent.

Moring and Lantz (1975) described the results of logging and road construction on sediment levels in three tributaries of the Alsea River in western Oregon. One watershed was entirely clearcut and burned with no attempt to protect the stream; 30 percent of the second watershed was clearcut in patches and a buffer strip of riparian vegetation was left along the stream; the third watershed was left unlogged as a control. Sediment in both experimental streams increased and the intragravel environment was degraded for incubation. Dissolved oxygen and water velocities within the streambed were reduced. These conditions persisted for several years.

Another potential impact of roads on spawning habitat occurs at stream fords, which are often located on gravelly riffles where anadromous salmonids spawn. If spawning occurs during a period of traffic use, the redds are often compacted and embryos suffer high mortality. If these fords are used by tractors or wheeled skidders, severe rutting at the approaches can occur, resulting in abnormal drainage and erosion. Large amounts of sediment thus can be introduced into the stream. Even if the forded streams have no onsite fishery values, the impacts are often transmitted to spawning areas downstream.

Encroachment of roads into the flood plain of streams used for spawning can affect the quality of spawning habitat in several ways. Removal of riparian vegetation can increase water temperatures and reduce hiding cover for both adult and juvenile salmonids. Narrowing of the channel caused by road construction can increase water depth and velocity and cause down-cutting and loss of gravels used for spawning. Side channels and flood channels where much spawning and rearing occurs are often permanently lost by channel encroachment and realignment. Under natural conditions, riffles are usually somewhat stable even during flood flows (Leopold et al. 1964), and gravels suitable for spawning tend to occur at the same locations each year. When a streambank is straightened and stabilized to accommodate a road, pools are often lost and boulder riffles unsuitable for spawning are increased. Also, when lateral migration of the channel is halted by nonerosive material such as riprap, flows are forced into a restricted area where stream energy is increased and rapid channel degradation occurs. Such an area often becomes totally unsuitable for spawning.

Some spawning habitat in most watersheds is lost because of bridge and culvert installations. Culverts placed in spawning areas effectively remove habitat equal to the length of the culvert, plus any area above and below that is realigned and stabilized to protect the culvert. Exceptions might include superspan and bottomless culverts, where natural stream bottoms remain. Bridges need not affect spawning areas, but if footings encroach into the channel and the stream is straightened and stabilized above and below the bridge, considerable spawning habitat can be lost.

Regular road maintenance is needed to protect spawning areas of salmonids, because deteriorating roads add large volumes of sediment to streams. In 1979, an assessment survey of forest practices in Washington concluded that a major source of sediment delivered to streams was inadequate road maintenance. Plugged cross-culverts and logging debris in drainage ditches were identified as primary causes of water quality problems. Most individual effects were judged to be of low impact, but the cumulative effects of many such occurrences can be significant (Sachet et al. 1980).

Timber management activities such as harvest scheduling, cutting systems, felling, yarding, and other silvicultural activities generally have less profound effects on spawning and incubation than do forest roads. Harvesting techniques that bare large amounts of mineral soil, such as tractor yarding and skidding, and cutting schedules that allow an entire watershed to be cut in a few years can increase sediment production enough to reduce the quality of spawning habitat. Felling has little effect on spawning habitat unless trees are felled directly into spawning areas. Cable yarding also has little effect if no logs are yarded through or across streams or riparian vegetation. Skyline systems that suspend the leading end of logs during yarding

tend to reduce sedimentation, but when logs are "flown" over streams and riparian vegetation, the riparian community is usually damaged by dangling logs and raising and lowering of cables in "skyroads". Slash burning and use of herbicides, pesticides, fertilizers, and fire retardants rarely affect spawning habitat if direct contamination of streams is prevented and riparian vegetation is protected (Norris et al. 1983).

Large woody debris from logging activities usually has a positive effect on spawning habitat of salmonids. Large trees with rootwads attached tend to stabilize channels, trap gravels suitable for spawning, and create seasonal flow in flood channels and side channels that are important spawning areas for several species of salmonids. Large debris also provides resting pools and cover important to adult salmonids on spawning migrations in small streams. Both the normal character of small forest streams, and the spawning requirements of salmonids have developed in the presence of an abundance of large organic debris.

On the other hand, logging slash that consists of an abundance of small organic debris can have several negative effects on spawning habitat. Stability of gravels can be jeopardized when a large amount of logging debris is introduced to streams (Hall and Baker 1975, Narver 1971, Swanson and Lienkaemper 1975). Large accumulations of slash can scour channels and cause instability during high-flow events (Helmers 1966), and cause routing and redeposition of gravels around debris accumulations. Small debris that infiltrates stream gravel can deplete intragravel dissolved oxygen (Hall and Lantz 1969, Ponce 1974) and cause mortality of incubating salmonid embryos.

Rearing

The importance of streams and lakes to rearing salmonids varies by species. Some resident salmonids, such as juvenile sockeye salmon and kokanee, rear primarily in lakes and are generally little affected by forest management activities during rearing. Most salmonids, however, rear in streams, and depending on duration of freshwater residency, are affected by habitat changes caused by roads and forest management. Anadromous species such as pink salmon, chum salmon, and fall chinook salmon rear in streams for only a short time before entering estuaries or the ocean, so the potential for impact related to timber harvest is reduced. Anadromous species that rear in small streams for a year or more such as coho, some spring chinook, steelhead, and cutthroat, are highly vulnerable to habitat changes caused by timber management activities. Resident species, primarily rainbow and cutthroat trout, that spend their entire lives in small streams must accommodate to environmental changes or perish. Because nearly all small streams in the western portions of Oregon and Washington have populations of resident or anadromous salmonids that rear in freshwater for a year or more, forest management activities must be designed to protect these fish.

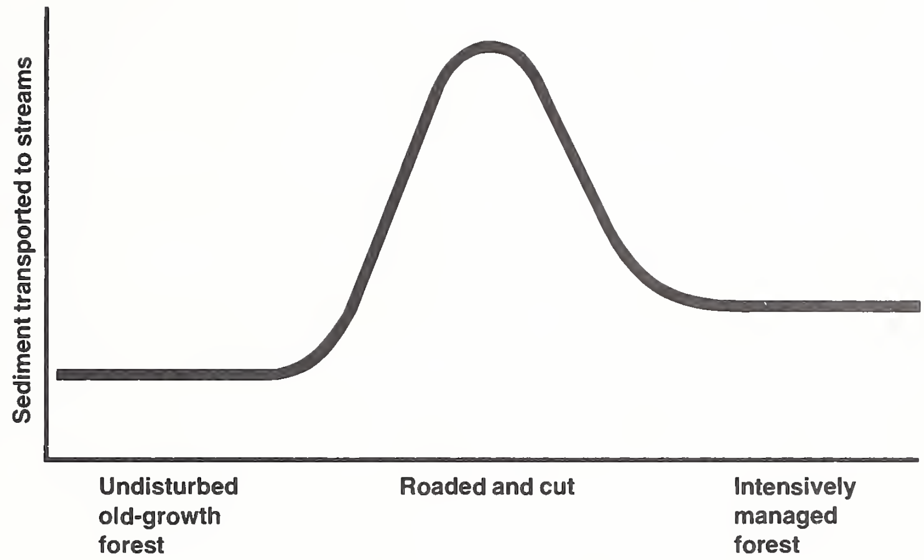


Figure 15.—Expected movement of sediment to streams from a watershed converted from old-growth timber to intensively managed stands.

Salo and Cederholm (1981) summarized the effects of land management that could operate in a cumulative manner on rearing salmonids or other populations as follows:

- Increased stream sedimentation—either as suspended or deposited sediments;
- Temperature changes—either diurnal or seasonal, resulting in extremes greater than those occurring naturally;
- Changes in physical habitat—brought about directly or indirectly by either excessive debris loading or excessive stream cleanout (also loss of old-growth riparian timber—the primary source of large organic debris in streams);
- Changes in water quality (such as dissolved oxygen, nutrients, pesticides); and
- Changes in water quantity and flow patterns—the net gain or loss of streamflow by removal of vegetation (interception, absorption, and transpiration).

The sources of sediment from timber management that affect rearing salmonids are the same as those that affect spawning. Roads are the primary source with cutbank and fillslope failures, road-surface erosion, ditch erosion, and failure of drainage structures contributing large amounts of sediment. Tractor yarding and site preparation can also be heavy contributors. Sediment production generally increases dramatically when old-growth forests are roaded and harvested. Sediment levels are likely to establish a new equilibrium above base levels and remain there as long as the lands are intensively managed for timber (fig. 15).

As with spawning, small streams suffer the greatest risk of degradation of rearing habitat; soils, precipitation, and geomorphology within a watershed determine the degree of risk. The maximum risk of damage from sedimentation covers an extensive area of western Washington and Oregon, where surface erosion and mass wasting (debris torrents, landslides) are prevalent. Streams in mountainous areas with sedimentary or granitic soils that receive more than 50 inches annual precipitation are the most vulnerable. Salmonid rearing habitat can also be degraded by timber management in other geographic areas, but the risk of damage is substantially lower.

The effects of sediment on rearing habitat have been studied experimentally and in natural streams. In experiments in Idaho, excessive sediment (sufficient to cause channel aggradation) was found to alter aquatic insect populations in riffles, reduce summer rearing capacity in pools, and reduce winter carrying capacity when deposition occurred in interstitial spaces of stream substrates (Bjornn et al. 1977). Channel aggradation in western Oregon and Washington tends to fill rearing pools with sediment and increase riffle habitat. Because juvenile coho salmon in streams are strongly associated with pools (fig. 16), and juvenile

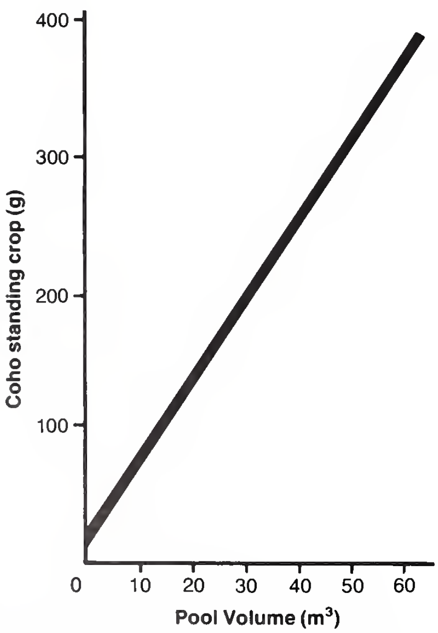


Figure 16.—Relation of pool volume to standing crop of juvenile coho salmon (Nickelson and Hafele 1978).

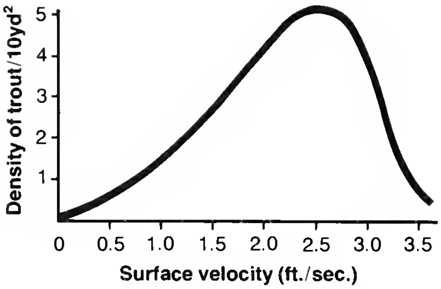


Figure 17.—Relation of surface velocity to the density of yearling and older steelhead trout parr (adapted from Everest and Chapman 1972, converted to English units).

steelhead are strongly associated with riffles (fig. 17), loss of pool habitat and an increase in riffles would likely reduce or eliminate coho, but maintain some steelhead production. The standing crop of older age-classes of steelhead would be reduced, however, because yearling and older steelhead do not favor sandy or gravelly substrates. Consequently, the primary effect for species preferring either riffles or pools would be reduced smolt production. The effects of sediment on rearing habitat appear to be more serious in the absence of large woody debris which, as previously mentioned, acts as a scour agent to maintain pools and move sediment onto the flood plain at high streamflows.

Not all deposition in streams is detrimental to salmonid production, however. The degree of risk from accelerated erosion appears to be related to the amount and textural composition of material entering stream channels. Everest and Meehan (1981) noted that debris torrents on Knowles Creek, Oregon, actually improved habitat for salmonids in an area where the stream substrate was composed primarily of bedrock. Addition of large rubble, cobble, and large woody debris increased habitat diversity, spawning and pool area, and increased the standing crop of juvenile coho salmon in the study area.

Suspended sediment resulting from forest management can interfere with feeding and growth of salmonids (Crouse et al. 1981; Noggle 1978; Sigler and Bjornn 1980) (fig. 18) and angler behavior (Puckett 1975) (fig. 19). Because juvenile salmonids are sight-feeders, water with a large sediment load (in excess of 50 nephelometric turbidity units) at water temperatures above 41°F generally reduces feeding success, growth, and competitive ability (Sigler and Bjornn 1980). Chronically turbid waters, particularly during spring, can significantly reduce growth of salmonid fry. Also, angling generally ceases when suspended sediment concentrations cause a stream to become "off color" (exceeding 20 Jackson turbidity units) (Puckett 1975). Even if fish production is unaffected, angling opportunities can be substantially reduced.

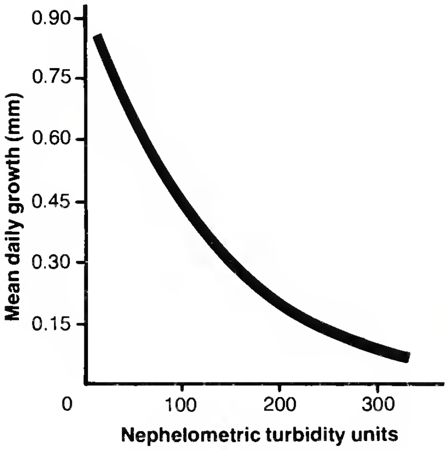


Figure 18.—Relation of water turbidity to growth of steelhead trout fry (adapted from Sigler and Bjornn 1980).

The shift from old-growth forests to intensively managed forests will be accompanied by a new and higher temperature equilibrium in summer in most watersheds (fig. 20). Canopies of

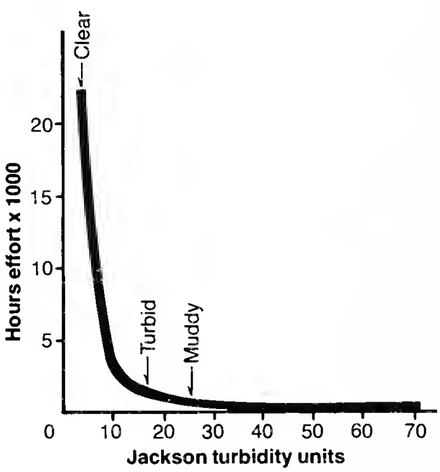


Figure 19.—Relation of water turbidity to angling effort, Eel River, California, 1972-1973 (Puckett 1975).

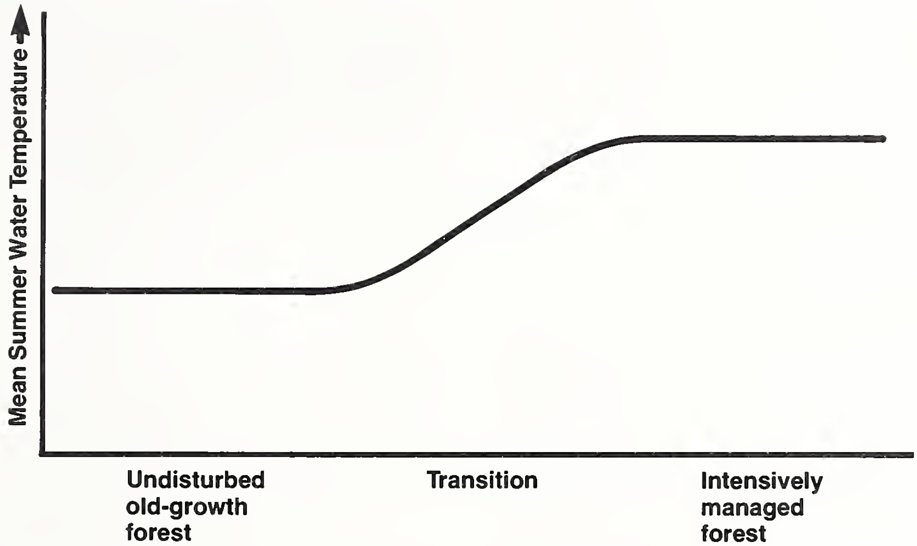


Figure 20.—Probable relation of temperature of streamflow exiting a watershed in summer to intensity of timber management within the watershed.

old-growth timber provide shade for small streams and minimize solar heating in summer. In intensively managed forests, depending on harvest scheduling, from 20 to 50 percent or more of the stream mileage in a watershed could be partially or completely exposed at some time during a rotation as timber is cut and regenerated on a sustained basis.

Studies of the effects of canopy removal on stream temperature indicate that removal generally causes a substantial increase in water temperature and this affects fish production in the immediate area, as well as in downstream waters. Extreme increases in temperature may result in direct mortality. Lesser increases may produce sublethal effects, such as cessation of growth, increased incidence of disease, and increased competition from nongame species that are more efficient at warmer temperatures. On the other hand, in very cold water systems, temperature increases may enhance onsite fish production.

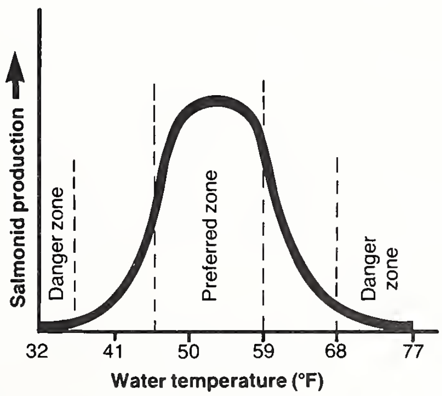
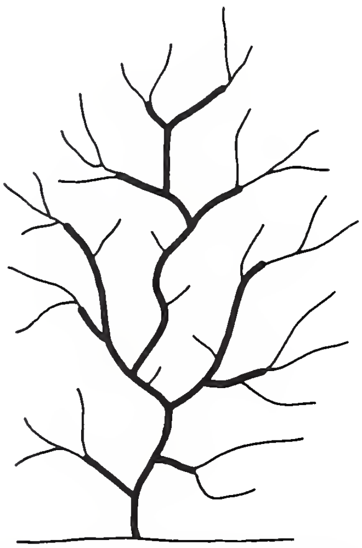


Figure 21.—Temperature preference zone and danger zones for rearing and incubating anadromous salmonids (adapted in part from Brett 1952).

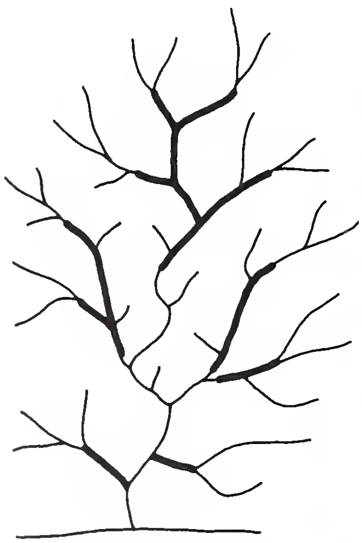
The effects of canopy removal on stream temperature are roughly predictable (Brown 1969). Temperature effects are most critical during summer when juveniles are rearing and during winter when embryos are incubating. In general, anadromous salmonids become stressed when summer water temperatures exceed 70°F, and mortality of salmonids might occur if temperatures exceed 77°F (fig. 21). Lethal or near-lethal high temperatures (Moring and Lantz 1974) or low temperatures (Chapman 1962) can result from removal of riparian vegetation bordering streams. If water temperatures in winter fall low enough to allow formation of anchor ice in areas where salmonid eggs are incubating, complete mortality of embryos can result (fig. 21).

Small streams are more subject to temperature changes than large streams. In some geographic areas, physical and climatic features cause a greatly elevated risk of thermal damage to small streams. In western Oregon, the maximum risk of damage from solar heating occurs in the southwest, the inland portions of the Coast Ranges, and low elevation foothills of the Cascade Range. Western Washington streams tributary to southern Puget Sound, the foothills of the southern Cascade Range, and the southwest portion of the state are also subject to solar heating problems. Streams in these areas can reach lethal temperatures for salmonids as a result of extensive clearcutting. In general, temperature problems in other parts of the region are less acute, but streams are still vulnerable to sublethal temperature increases that can seriously depress production of rearing salmonids.

Although the effects of elevated temperature in any one stream may not produce immediate effects on salmonid production, cumulative effects from several tributaries can result in loss of mainstem rearing habitat downstream (fig. 22). Such effects constitute a serious potential loss of rearing area for salmonids in both western Oregon and Washington.



A. Undisturbed old-growth forest.



B. Intensively managed forest.

Figure 22.—Hypothetical example of potential short-term loss of mainstem rearing habitat as a result of cumulative temperature increases from harvest of riparian timber along tributaries. Heavy black line represents rearing area.

Damage from decreased water temperatures in winter can occur in cold climates, where insulating streamside vegetation has been removed. High risk areas are few on the west side, but such effects could occur in a few high Cascade and Columbia Gorge streams.

Large organic debris has historically been an abundant and important part of natural forest streams (Sedell et al. 1981). Recognition of its importance in streams of western states developed from a forest management perspective (Froelich 1973, Heede 1972, Marzoff 1978) and from an ecosystem perspective (Bilby 1981, Bibly and Likens 1980, Meehan et al. 1977, Sedell and Triska 1977, Swanson et al. 1976).

The relation of large woody debris to rearing salmonids has been clarified through recent research, and some striking trends have been noted (Baker 1979, Franklin et al. 1981, Meehan et al. 1977, Sedell et al. 1982, Sedell and Triska 1977). In general, the more habitat diversity (pools, riffles, cover, off-channel and flood-channel habitat) created by large woody debris, the greater the rearing potential for salmonids (fig. 23). Abundance of juvenile cutthroat and steelhead in second- and third-order streams is closely correlated with cover (fig. 24). Most cover in small forest streams is provided by large woody debris. Coho and other pool-dwelling salmonids in small streams also depend on pools and cover created by large organic debris. Woody debris is important for enhancing both rearing habitat

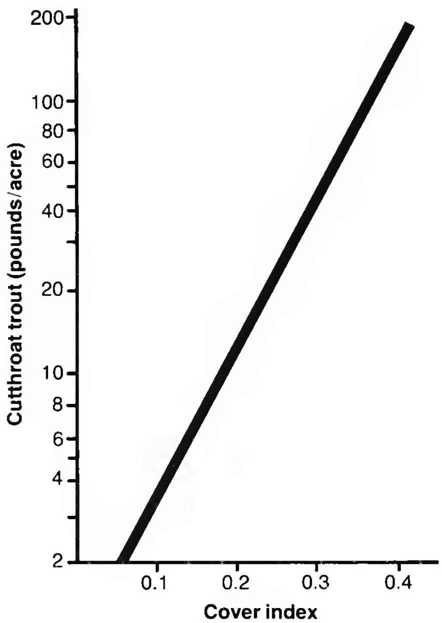


Figure 24.—Relation of cover index to standing crop of cutthroat trout in three Oregon coastal streams (adapted from Nickelson and Reisenbichler 1977) (Note log scale).

Figure 23.— Large woody debris in streams provides complex and productive habitat for salmonids.

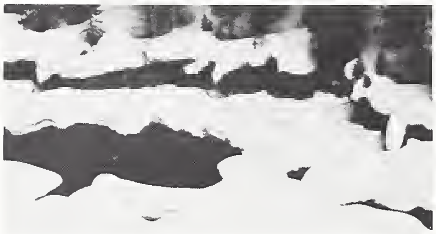


Figure 25.—Productive salmonid habitat needs adequate cover for winter survival.

during summer in streams up to seventh-order and for providing survival cover in off-channel areas during winter (fig. 25). Large woody debris tends to direct fine sediment from the channel to the flood plains and store gravels and rubble in the channel. It also provides a source of nutrients and a substrate for biological activity.

Intensive forest management, however, will remove much of the source material for recruitment of large debris to stream channels and will result in less woody debris in streams (fig. 26). Shortened timber rotations and harvest of smaller trees will eventually result in stream channels nearly devoid of large woody debris unless positive steps are taken to insure continued recruitment of large woody material to channels. Such a long-term loss of debris would reduce habitat complexity and overall productivity of streams for salmonids (fig. 27). Future streamside management should plan for continued recruitment of large woody debris to stream channels.

Although logging activities sometimes increase nutrient levels in rearing areas, the effects are usually minor. Increases in nutrients in streams after logging and slash burning generally have been low (Tiedemann et al. 1979). Lotspeich et al. (1970) concluded that changes in the chemical makeup of water after a wildfire in Alaska were below the levels required to exert an impact on stream macroinvertebrates. Similar conclusions were reached by Wood (1977) for macroinvertebrates and by Hoffman and Ferreira (1976) for production of periphytic algae. Toxic concentrations of nutrients and heavy metals have been found only where logging residue has been burned directly in stream channels (Fredriksen 1971).

Figure 27.—Overzealous removal of large woody debris from stream channels can damage habitat and reduce salmonid populations.

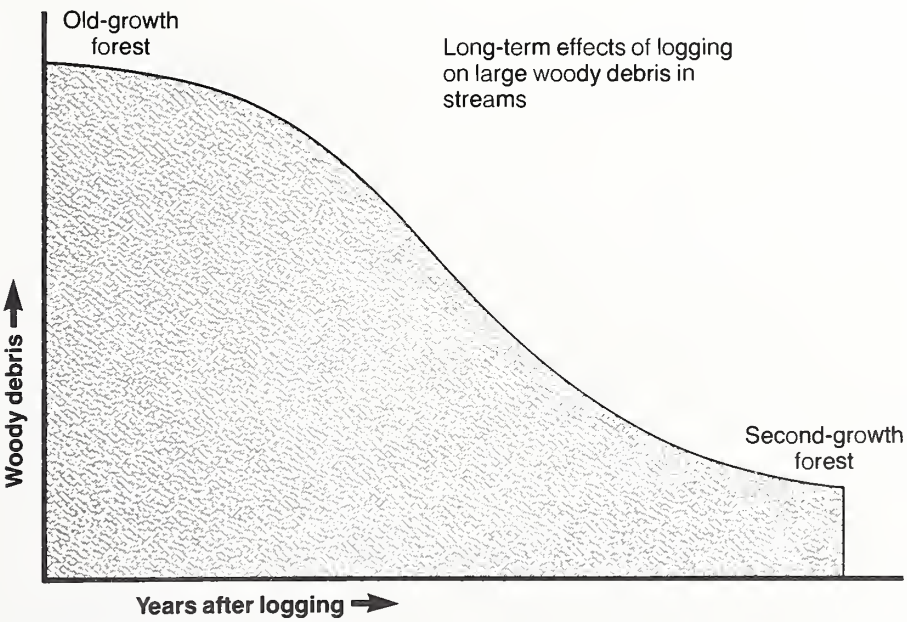


Figure 26.—Probable relation of large woody debris in streams in undisturbed old-growth to intensively managed forests.

Logging can also affect streamflow, but the effects are not well documented in large watersheds. In small watersheds, clearcutting frequently increases base flow during summer low-flow periods by reducing interception and transpiration losses and making more water available for stream flow. Generally such increases are temporary and may disappear in less than 5 years (Harr 1979). In large watersheds, the cumulative effects of timber harvest could cause an increase or decrease in flow if the rate of accumulation and melting of snowpacks is altered or the rate of ground water recharge is affected. These variations in streamflow may be either beneficial or detrimental to salmonid rearing habitat depending on the season and circumstances within a particular drainage.

Summary of The Relation of Logging to Fish Habitat

The major habitat alterations from timber management that reduce productivity of salmonid habitat are increases in water temperature and sediment in streams, and long-term loss of large woody debris from stream channels. Changes in water quality and quantity also are important to spawning and rearing salmonids. If managers plan timber-harvest operations to maintain or reduce water temperature and sedimentation, make provisions for long-term recruitment of large woody debris, and protect riparian vegetation and migratory access routes, productive habitat for salmonids will either be maintained or enhanced. Management options for accomplishing these objectives are discussed in the following section.

Management Considerations

Streams in old-growth forests usually have established an equilibrium between solar radiation and water temperature, and between the rate of accumulation of sediment and woody debris and the rate of biological and physical processing of these habitat components. Logging can shift these equilibria, alter water quality and habitat stability, and cause changes in salmonid populations. Nearly all forest management activities conducted near small streams or anywhere in steep, unstable watersheds, have direct effects on salmonid habitat. Most timber sale planning and forest practice rules relating to streams are designed to maintain the preharvest equilibrium of streams. Consequently, managers usually attempt to protect and maintain the current quality and productivity of salmonid habitats in watersheds that are being logged. When suitable habitats for salmonids are maintained, an adequate range of habitats for native nonsalmonid fish species also results.

Timber-harvesting options designed to protect water quality and fish habitat are fairly well developed. A list of options that have been most effective in minimizing disturbances to habitat of salmonids in small streams (first- to fourth-order) is included below. The list is broad-based, contains only key options, and is by no means exhaustive. Nevertheless, the options listed often represent the best management practices available for coordination of fish habitat and timber harvest.

Roads

Location and Design

Considerations

Protect riparian vegetation; minimize sediment transport to streams; prevent stream channeling and clearing at crossings; maintain upstream and downstream access for anadromous and resident salmonids.

Options

- Locate roads on ridgetops or upslope benches, and minimize midslope roads except where necessary to access preferable locations;
- On steep ground, use full-bench subgrade, minimum width, and excavation;
- Vary grade to take advantage of topography;
- Avoid unstable ground;
- Provide culverts at all drainageways;
- Use bridges or open-bottom culverts to cross anadromous fish streams; and
- Provide frequent drainage to prevent ditch erosion and slope failures.

Road Construction

Considerations

Protect riparian vegetation; prevent sediment and debris from reaching streams; prevent stream channel changes (fig. 28).

Figure 28.—Properly located, constructed, and maintained forest roads offer little threat to productive salmonid habitat.

Options

- Pioneer with minimum size equipment;
- Halt construction in wet weather;
- End-haul excavated material in lieu of side casting on steep ground;
- Install culverts in fish-bearing streams on original stream grade if less than 0.5 percent and use baffled culverts where the grade is greater than 0.5 percent up to a maximum of 4 percent;
- Do not install culverts with grades exceeding 4 percent in fish-bearing streams;
- Conduct in-stream work during periods that will minimize damage to fisheries;
- Riprap culvert ends and provide energy dissipators to prevent erosion;
- Do not remove spawning gravel from streams;
- Revegetate or riprap exposed soil;
- Install trash racks on culvert inlets in nonfish-bearing streams;

- Asphalt pave stream crossing approaches on high-use roads, use two crossdrains on either side of the stream crossing; and
- Flume the downspouts of cross-drains and provide energy dissipators at the discharge end of the flumes.

Road Maintenance

Considerations

Prevent sedimentation; prevent sluice-out of road fills into streams; prevent debris-clogged culverts; prevent erosion of road surface.

Options

- Keep ditches open;
- Restrict mechanical cleaning of ditches to periods of dry weather;
- Remove unstable slash or small organic debris in channels for at least 50 feet above culvert inlet;
- Keep roads crowned;
- Patrol roads and drainage structures during intense storms;
- Maintain vegetative cover on cuts and fills;
- Do not control vegetation in ditches with herbicides; and
- Close roads not in use.

Timber Management Operations

Scheduling

Consideration

Spread impacts of harvesting in a watershed over entire rotation through incremental cutting.

Options

- In steep lands, schedule no more than 10 percent of watershed area for timber harvest in 1 year;
- Allow regrowth of riparian vegetation before cutting in adjacent riparian zones; and
- Schedule felling and yarding to minimize disturbance to streams and fish.

Design and layout of Cutting Units

Considerations

Minimize soil erosion and thermal pollution; protect streambanks and channel stability; minimize disturbance of riparian vegetation; provide source of large woody debris (fig. 29).

Options

- Clearcut in small patches;
- Leave riparian buffer strips containing large conifers along streams with on-site fish production;
- Select felling, yarding, and roading systems appropriate for terrain; and
- Avoid logging on steep headwalls with shallow, unstable soils.

Felling and Bucking

Considerations

Protect streams and riparian vegetation from falling timber.

Options

- Fell timber uphill away from streams;
- Use jacks or lines to fell timber directionally on steep slopes or in buffer strips; and
- Leave high stumps on lower slopes to stop timber and slash from rolling down into streams.

Yarding

Considerations

Minimize ground disturbance and compaction; protect riparian vegetation; protect woody debris embedded in channel; select yarding system to minimize road density.

Options

- Aerial yard with skylines or helicopters on steep, unstable ground and in buffer strips;
- Hand-haul tractor drumlines into buffer strips;
- Tree-length yard to minimize tractor entry in buffer strips;
- Use full log suspension logging systems in riparian zone corridors; and
- Do not remove more than 25 percent of original crown cover in riparian zone corridors.

Debris Management

Considerations

Protect large woody debris in streams; provide for future recruitment of large woody debris to streams; prevent accumulation of logging slash in streams.

Options

- Leave large stable debris (especially cedar) in, over, and around streams in unbucked condition;
- Leave large conifers, especially cedar, 18 inch d.b.h. or larger and hardwoods in riparian zones as a source of future large organic debris for streams;
- Broadcast burn small debris in spring when ground is damp;
- Remove small logging slash and debris from streams during the summer months;

Figure 29.—The present and future intergrity of streams can be protected with "buffer strips" containing large trees.

- Place small debris removed from streams in stable piles above the high-water mark to prevent reentry; and
- In steep country leave live trees to provide trash racks above stream channels and riparian areas.

Planting

Considerations

Prevent soil erosion; provide balanced organic input to streams by maintaining a mixed stand of both conifers and hardwoods in riparian zones; provide shade for exposed streams.

Options

- Keep vehicles off unsurfaced roads in wet weather; and
- Plant conifers and, if necessary, deciduous trees in riparian zones.

Herbicide Application

Considerations

Protect riparian vegetation; prevent contamination of water.

Options

- Avoid aerial application or hand application that would contaminate streams, springs, swamps, or bogs; and
- Clean growth from roadside ditches mechanically rather than with herbicides.

Precommercial Thinning

Considerations

Prevent slash and debris from entering stream channels; prevent soil erosion.

Options

- Avoid thinning within 100 feet of streams except to enhance riparian vegetation;
- Remove by hand any slash that enters stream channels; and
- Keep vehicles off unsurfaced roads in wet weather.

Commercial Thinning

Considerations

Prevent slash and debris from entering stream; protect riparian vegetation. Also, the considerations and options listed for Scheduling, Design and Layout of Cutting Units, Felling and Bucking, and Yarding will apply to a commercial thinning operation as well.

Options

- Avoid thinning within 100 feet of stream except to enhance riparian vegetation; and
- Avoid yarding through stream or buffer strip.

Insecticide Application

Consideration

Prevent contamination of water.

Option

- Avoid aerial application or hand application that would contaminate streams, springs, bogs, or marshes.

Fire Control

Considerations

Prevent soil erosion; prevent contamination of streams with fire retardants.

Options

- Reestablish vegetation on burned areas and fire lines;
- Avoid aerial retardant drops that would contaminate streams, springs, bogs, or marshes;
- Avoid burning sequences that would damage more than 20 percent of the residual vegetation;
- Nonburning techniques may be required to reduce fuel loading adjacent to riparian or streamside buffer zones.

References Cited

Aho, R. S. A population study of cutthroat trout in an unshaded and shaded section of stream. Corvallis, OR: Oregon State University; 1976. 87 p. Thesis.

Albrecht, M. Die wirkung des Luchtes auf die quantitative Verteilung der Fauna in Fliessgewasser. Limnologica. 6: 71-82; 1968.

Anderson, H. W. Relative contributions of sediment from source areas, and transport processes. In: Krygier, J. T.; Hall, J. D., eds. Forest land uses and the stream environment: Proceedings of a symposium; 1970 October 19-21; Corvallis, OR. Corvallis, OR: Oregon State University; 1971: 55-63.

Baker, C. The impacts of logjam removal on fish populations and stream habitat in western Oregon. Corvallis, OR: Oregon State University; 1979. 86 p. Thesis.

Bell, M. C. Fisheries handbook of engineering requirements and biological criteria: useful factors in life history of most common species. 1973. Unpublished report submitted to Fisheries Engineering Research Program, Corps of Engineers, North Pacific Division, Portland, OR.

Bilby, R. E. Role of organic debris dams in regulating the export of dissolved and particulate matter from a forested watershed. Ecology. 62: 1234-1243; 1981.

Bilby, R. E.; Likens, G. E. Importance of organic debris dams in the structure and function of stream ecosystems. Ecology. 61: 1107-1113; 1980.

Bisson, P. A.; Sedell, J. R. Salmonid populations in logged and unlogged stream sections of western Washington. In: Merrill, T. R.; Meehan, W. R., eds. Proceedings, symposium on fish and wildlife relationships in old-growth forests; 1982 April 12-15; Juneau, AK. [in press].

Bjornn, T. C. Survival and emergence of trout and salmon in various gravel-sand mixtures. In: Proceedings, forum on the relation between logging and salmon; 1968 February

8-9; Juneau, AK. Juneau, AK: American Institute of Fisheries Research Biologists and Alaska Department of Fish and Game; 1968: 80-88.

Bjornn, T.C.; Brusven, M.A.; Molnau, M.P. [and others]. Sediment in streams and its effect on aquatic life. Moscow, ID: University of Idaho; Tech. Completion Rep., Water Resour. Res. Inst. Proj. B-025-IDA. 1974. 27 p.

Bjornn, T. C.; Brusven, M. A.; Molnau, M. P. [and others]. Transport of granitic sediment in streams and its effects on insects and fish. Bull. 17. Moscow, ID: University of Idaho; Forest, Wildlife, and Range Experiment Station; 1977. 43 p.

Brett, J. R. Temperature tolerance in young Pacific salmon, genus *Oncorhynchus* sp. J. Fish. Res. Board Can. 9(6): 265-323; 1952.

Briggs, J. C. The behavior and reproduction of salmonid fishes in a small coastal stream. Fish. Bull. 94. Sacramento, CA: California Department of Fish and Game; 1953. 62 p.

Brown, G. W. Predicting temperatures of small streams. Water Resour. Res. 5: 68-75; 1969.

Bustard, D. R.; Narver, D. W. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). J. Fish. Res. Board Can. 32: 667-680; 1975.

Cederholm, C. J. Personal communication. Natural Resource Scientist/Fish Biologist, Olympic Area Office. State of Washington, Department of Natural Resources, Forks, WA. 1982.

Cederholm, C. J.; Reid, L. M.; Salo, E. O. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. In: Salmon-spawning gravel: a renewable resource in the Pacific Northwest: Proceedings of a conference; 1980 October 6-7; Seattle, WA. Seattle, WA: University of Washington, College of Fisheries; 1981. 35 p.

Cederholm, C. J.; Salo, E. O. The effects of landslide siltation on salmon and trout spawning gravels of Steqauleho Creek and the Clearwater River Basin, Jefferson County, Washington, 1972-1978. Seattle, WA: University of Washington; 1979; Final Report, Part III, Fisheries Research Institute, FRI-UW-7915. 99 p.

Chapman, D. W. Effects of logging upon fish resources of the West Coast. J. For.60(8): 533-537; 1962.

Chapman, D. W. Food and space as regulators of salmonid populations in streams. Am. Midl. Nat. 100: 345-357; 1966.

Chapman, D. W.; Bjornn, T. C. Distribution of salmonids in streams with special reference to food and feeding. In: Northcote, T. G., ed. Proceedings, symposium on salmon and trout in streams. H. R. MacMillan lectures in fisheries; 1968 February 22-24; Vancouver, BC. Vancouver, BC: University of British Columbia; 1969.

Chapman, D. W.; Knudsen, E. Channelization and livestock impacts on salmonid habitat and biomass in western Washington. Trans. Am. Fish. Soc. 109: 357-363; 1980.

Collings, M. R.; Smith, R. W.; Higgins, G. T. The hydrology of four streams in western Washington as related to several Pacific salmon species. Open-file Rep. Tacoma, WA: U.S. Department of the Interior, Geological Survey; 1970. 158 p.

Cordone, A. J.; Kelly, D. E. The influence of inorganic sediment on the aquatic life of streams. Calif. Fish and Game. 47: 189-228; 1961.

Crouse, M. R.; Callahan, C. A.; Malueg, K. W.; Dominguez, S. E. Effects of fine sediments on growth of juvenile coho salmon in laboratory streams. Trans. Am. Fish. Soc. 110: 281-286; 1981.

Davis, G. E.; Forester, J.; Warren, C. E.; Doudoroff, P. The influence of oxygen concentration on the swimming performance of juvenile Pacific salmon at various temperatures. Trans. Am. Fish. Soc. 92(2): 111-124; 1963.

Doudoroff, P.; Warren, C. E. Environmental requirements of fishes and wildlife—dissolved oxygen requirements of fishes. In: Biological problems in water pollution, 3d seminar 1962, PHS Publ. 999-WP-25, Spec. Rep. 141. Corvallis, OR: Oregon Agricultural Experiment Station, Oregon State University; 1965: 145-155.

Erman, D. C.; Newbold, J. D.; Roby, K. B. Evaluation of streamside bufferstrips for protecting aquatic organisms. No. 165. Davis, CA: University of California, Water Resources Center; 1977. 39 p.

Everest, F. H. Ecology and management of summer steelhead in the Rogue River. Fish. Res. Rep. 7. Corvallis, OR: Oregon State Game Commission; 1973.

Everest, F. H.; Chapman, D. W. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. J. Fish. Res. Board Can. 29(1): 91-100; 1972..

Everest, F. H.; Harr, R. D. Silvicultural treatments. In: Meehan, W. R., tech. ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. Gen. Tech. Rep. PNW-96. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1982. 19 p.

Everest, F. H.; Meehan, W. R. Forest management and anadromous fish habitat productivity. In: 46th North Am. Wildl. and Nat. Resourc. Conf. Trans.; Washington, DC: Wildlife Management Institute; 1981: 521-530.

Franklin, J. F.; Cromak, K.; Denison, W. [and others]. Ecological characteristics of old-growth Douglas-fir forests. Gen. Tech. Rep. PNW-118. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 48 p.

Fredriksen, R. L. Comparative chemical water quality—Natural and disturbed streams following logging and slash burning. In: Krygier, J. T.; Hall, J. D., eds. Proceedings, forest land uses and the stream environment symposium; 1970 October 19-21: Corvallis, OR. Corvallis, OR: Oregon State University; 1971: 125-137.

Fredriksen, R. L. Impact of forest management on stream water quality in western Oregon. In: Pollution abatement and control in the forest products industry. 1972. Reproduced by the U.S. Department of Agriculture, Forest Service, Portland, OR.

Froehlich, H. A. Natural and man-caused slash in headwater streams. Loggers Handb., vol. 33; 1973. 8 p.

Gibbons, D.R.; Salo, E. O. An annotated bibliography of the effects of logging on fish of the western United States and Canada. Gen. Tech. Rep. PNW-10. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1973. 145 p.

Gregory, S. V. Effects of light, nutrients, and grazing on periphyton communities in streams. Corvallis, OR: Oregon State University; 1980. 151 p. Dissertation.

Hall, J. D.; Baker, C. O. Biological impacts of organic debris in Pacific Northwest streams. In: Proceedings, logging debris in streams workshop; 1975 September 9-10; Corvallis, OR. Corvallis, OR: Oregon State University; 1975. 13 p.

Hall, J. D.; Lantz, R. L. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. In: Northcote, T. G., ed. Proceedings, symposium on salmon and trout in streams. H. R. MacMillan lectures in fisheries; 1968 February 22-24; Vancouver, BC. Vancouver, BC: University of British Columbia; 1969: 355-357.

Hanson, D. L. Habitat selection and spatial interaction in allopatric and sympatric populations of cutthroat and steelhead trout. Moscow, ID: University of Idaho; 1977. 66 p. Dissertation.

Harr, R. D. Effects of timber harvest on streamflow in the rain-dominated portion of the Pacific Northwest. In: Proceedings, workshop on scheduling timber harvest for hydrologic concerns; 1979 November 27-29; Spokane, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979. 43 p.

Hausle, D. A. Factors influencing embryonic survival and emergence of brook trout (*Salvelinus fontinalis*). Stephens Point, WI: University of Wisconsin; 1973. 38 p. Thesis.

Heede, B. H. Influence of a forest on the hydraulic geometry of two mountain streams. Water Resour. Bull. 8: 523-530; 1972.

Helmers, A. E. Some effects of log jams and flooding in a salmon spawning stream. Res. Note NOR-14. Juneau, AK: U.S. Department of Agriculture, Forest Service, Northern Forest Experiment Station; 1966. 4 p.

Hoffman, R. J.; Ferreira, R. F. A reconnaissance of effects of a forest fire on water quality in Kings Canyon National Park. Open-File Rep. 76-497. Menlo Park, CA: U.S. Department of the Interior, Geological Survey; 1976. 17 p.

Hughs, D.A. Mountain streams of the Barberton area, eastern Transvaal: Part II. The effect of vegetational shading and direct illumination on the distribution of stream fauna. Hydrobiologia. 27: 401-438; 1966.

Hunter, J. W. A discussion of game fish in the State of Washington as related to water requirements. Olympia, WA: Washington State Department of Game; 1973. 66 p.

Iwamoto, R. N.; Salo, E. O.; Madej, M. A.; McComas, R. L. Sediment and water quality: a review of the literature including a suggested approach for water quality criteria. Seattle, WA: University of Washington, Fisheries Research Institute; 1978; EPA 910/9-78-048. 151 p.

Keller, E. A.; Swanson, F. J. Effects of large organic material on channel form and fluvial processes. Earth Surf. Processes. 4: 361-380; 1979.

Koski, K. V. Effects of sediment on fish resources: management seminar. Lake Limerick, WA. Olympia, WA: Washington Department of Natural Resources; 1972. 36 p.

Larse, R. W. Prevention and control of erosion and sedimentation from forest roads. In: Krygier, J. T.; Hall, J. D., eds. Proceedings, forest land uses and the stream environment symposium; 1970 October 19-21; Corvallis, OR. Corvallis, OR: Oregon State University; 1971: 76-83.

LeCren, E. D. Estimates of fish populations and production in small streams in England. In: Northcote, T. G., ed. Proceedings, symposium on salmon and trout in streams: H. R. MacMillan lectures in fisheries; 1968 February 22-24; Vancouver, BC. Vancouver, BC: University of British Columbia; 1969: 269-280.

Leopold, L. B.; Wolman, M. G.; Miller, J. P. Fluvial processes in geomorphology. San Francisco: W. H. Freeman and Co.; 1964. 522 p.

Lister, D. B.; Genoe, H. S. Stream habitat utilization by cohabitating underyearling chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon in the Big Qualicum River, British Columbia. J. Fish. Res. Board Can. 27(7): 1215-1224; 1970.

Lotspeich, F. B.; Mueller, E. W.; Frey, P. J. Effects of large scale forest fires on water quality in interior Alaska. College, AK: U.S. Department of the Interior, Federal Water Pollution Control Administration, Alaska Water Laboratory; 1970. 115 p.

Lyford, J. H.; Gregory, S. V. The dynamics and structure of periphyton communities in three Cascade Mountain streams. Verh. Int. Ver. Limnol. 19: 1610-1616; 1975.

Martin, D. J.; Salo, E. O.; White, S. T. [and others]. The impact of managed streamside timber removal on cutthroat trout and the stream ecosystem. Seattle, WA: University of Washington, College of Fisheries; 1981; Final Report, FRI-UW-8107. 65 p.

Marzoff, R. G. The potential effects of clearcutting and snagging on stream ecosystems. Washington, DC: U.S. Department of the Interior, 1978. 31 p.

Mason, J. C. Response of underyearling coho salmon to supplemental feeding in a natural stream. J. Wildl. Manage. 40(4): 775-778; 1976.

Meehan, W. R.; Swanson, F. J.; Sedell, J. R. Influences of riparian vegetation on aquatic ecosystems with particular reference to salmonid fishes and their food supply. In: Proceedings, importance, preservation and management of riparian habitat: a symposium; 1977 July 9; Tucson, AZ. Albuquerque, NM: U.S. Department of Agriculture, Forest Service; 1977: 137-145.

Moring, J. R.; Lantz, R. L. Immediate effects of logging on the freshwater environment of salmonids. Portland, OR: Oregon Wildlife Commission; 1974; Res. Div., Proj. AFS-58, Final Report. 101 p.

Moring, J. R.; Lantz, R. L. The Alsea watershed study: effects of logging on aquatic resources of three headwater streams of the Alsea River, Oregon: Part II. Changes in environmental conditions. Fish. Res. Rep. 9. Corvallis, OR: Oregon Department of Fish and Wildlife; 1975. 39 p.

Murphy, M. L.; Hall, J. D. Effects of clearcutting on predators and their habitat in small streams of the Cascade Mountains, Oregon. Can. J. Fish. and Aquat. Sci. 38(2): 137-145; 1980.

Murphy, M. L.; Hawkins, C. P.; Anderson, N. H. Effects of accumulated sediment on stream communities in different trophic environments. Trans. Am. Fish. Soc. 110: 469-478; 1981.

Narver, D. W. Effects of debris on fish production. In: Proceedings, forest land uses and the stream environment symposium; 1970 October 19-21; Corvallis, OR. Corvallis, OR: Oregon State University; 1971: 110-111.

Newbold, J. D.; Erman, D. C.; Roby, K. B. Effects of logging on macroinvertebrates in streams with and without buffer strips. Can. J. Fish. and Aquat. Sci. 37(7): 1076-1085; 1980.

Nickelson, T. E.; Hafele, R. E. Streamflow requirements of salmonids. Portland, OR: Oregon Department of Fish and Wildlife; 1978; Prog. Rep.; Contract 14-16-0001-77-538. 25 p.

Nickelson, T. E.; Reisenbichler, R. R. Streamflow requirements of salmonids. Portland, OR: Oregon Department of Fish and Wildlife; 1977; Prog. Rep; Contract 14-16-0001-4247. 24 p.

Noggle, C. C. Behaviorial, physiological, and lethal effects of suspended sediment on juvenile salmonids. Seattle, WA: University of Washington; 1978. 87 p. Thesis.

Norris, L. A.; Lorz, H. W.; Gregory, S. V. Forest chemicals: use, behavior, and impact on anadromous fish and their habitat. In: Meehan, W. R., tech. ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. Gen. Tech. Rep. PNW-96. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1983. 95 p.

Oregon Department of Fish and Wildlife. Unpublished data on file at the Oregon Department of Fish and Wildlife, Portland, OR. n.d.

Osborn, J. G. Effects of logging on cutthroat trout (*Salmo clarki*) in small headwater streams. Seattle, WA: University of Washington; 1980; Fish. Res. Inst. Rep. FRI-UW-8013. 89 p.

Peterson, N. P. The role of spring ponds in the winter ecology and natural production of coho salmon (*Oncorhynchus kisutch*) on the Olympic Peninsula, Washington. Seattle, WA: University of Washington; 1980. 96 p. Thesis.

Phillips, R. W. Influence of gravel size on survival and emergence of coho salmon and steelhead trout. In: Proceedings, 15th Northwest fish culture conference. 1964 December 2-3; Corvallis, OR. Corvallis, OR: Oregon State University; 1964. 90 p.

Phillips, R. W. Effects of sediment on the gravel environment and fish production. In: Proceedings, forest land uses and stream environment – a symposium. 1970 October 19-21; Corvallis, OR. Corvallis, OR: Oregon State University; 1971: 64-74.

Phillips, R. W.; Lantz, R. L.; Claire, E. W.; Moring, J. R. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Trans. Am. Fish. Soc. 104(3): 461-466; 1975.

Ponce, S. L. The biochemical oxygen demand of finely divided logging debris in stream water. Water Resour. Res. 10(5):983-988; 1974.

Puckett, L. Sport fisheries of the Eel River, 1972-1973. Eureka, CA: California Fish and Game; 1975. 35 p. Memorandum report.

Redding, J. M.; Schreck, C. B. Chronic turbidity and stress in juvenile coho salmon and steelhead trout. Corvallis, OR: Oregon Cooperative Fish Resource Unit, Oregon State University; 1980; PNW 1705-16, Final Report submitted to Forest Service. 84 p.

Reid, L. M. Sediment production from gravel-surfaced road, Clearwater Basin, Washington. Seattle, WA: University of Washington, Fisheries Research Institute; 1981. 247 p. Thesis.

Reiser, D. W.; Bjornn, T. C. Habitat requirements of anadromous salmonids. In: Meehan, W. R., tech. ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. Gen. Tech. Rep. PNW-96. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 54 p.

Sachet, J.; Keller, S.; McCoy, A. [and others]. An assessment of the adequacy of Washington's forest practice rules and regulations in protecting water quality. Tech. Rep. DOE80-7A. Olympia, WA: State of Washington, Department of Ecology; 1980. 102 p.

Salo, E. O.; Cederholm, C. J. Cumulative effects of forest management on watersheds – some aquatic considerations. In: Proceedings, Edgebrook conference on cumulative effects; 1980 June 2-3; Berkeley, CA. Berkeley, CA: University of California, Berkeley Press; 1981. 109 p.

Scott, W. B.; Crossman, E. J. Freshwater fishes of Canada. Bull. 184. Ottawa, ON: Fisheries Research Board of Canada; 1973. 966 p.

Sedell, J. R.; Bisson, P. A.; June, J. A. Ecology and habitat requirements of fish populations in the South Fork Hoh River, Olympic National Park. In: Proceedings, 2d conference on scientific research in National Parks; 1980 November 26-30; San Francisco, CA. Washington DC: National Park Service; vol. 7; 1981; NTIS NPS/ST-80/02-7.

Sedell, J. R.; Everest, F. H.; Swanson, F. J. Fish habitat and streamside management: past and present. In: Proceedings, National Society of American Foresters Annual Meeting; 1981 September 27-30; Orlando, FL. Washington, DC: Society of American Foresters; 1982: 244-245.

Sedell, J. R.; Triska, F. J. Biological consequences of large organic debris in Northwest streams. In: Proceedings, logging debris in streams workshop 2; 1977 March 21-22; Corvallis, OR. Corvallis, OR: Oregon State University; 1977. 10 p.

Sigler, J. W.; Bjornn, T. C. Effects of chronic turbidity on feeding, growth, and social behavior of steelhead trout and coho salmon. Moscow, ID: University of Idaho, Idaho Cooperative Fisheries Research Unit; 1980; Completion Rep. 157 p.

Smith, A. K. Development and application of spawning velocity and depth criteria for Oregon salmonids. Trans. Am. Fish. Soc. 1(2): 312-316; 1973.

Strahler, A. N. Quantitative analysis of watershed geomorphology. Trans. Am. Geophys. Union 38: 913-920; 1957.

Stuart, T. A. The leaping behavior of salmon and trout at falls and obstructions: freshwater salmon. Fish. Res. Rep. 28. Scotland: Home Department; 1962. 46 p.

Stuehrenberg. L. C. The effects of granitic sand on the distribution and abundance of salmonids in Idaho streams. Moscow, ID: University of Idaho; 1975. 49 p. Thesis.

Swanson, F. J.; Dyrness, C. T. Impact of clearcutting and construction on soil erosion by landslides in the western Cascade Range, Oregon. Geology. 3: 393-396; 1975.

Swanson, F. J.; Lienkaemper, G. W. The history and physical effects of large organic debris in western Oregon Streams. In: Proceedings, logging debris in streams workshop; 1975 September 9-10; Corvallis, OR. Corvallis, OR: Oregon State University; 1975. 18 p.

Swanson, F. J.; Lienkaemper, G. W.; Sedell, J. R. History, physical effects and management implications of large organic debris in western Oregon streams. Gen. Tech. Rep. PNW-56. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1976. 15 p.

Swanston, D. N. Mechanics of debris avalanching in shallow till soils of southeast Alaska. Res. Pap. PNW-103. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1970. 17 p.

Swanston, D. N.; Swanson, F. J. Timber harvesting, mass erosion, and steep land forest geomorphology in the Pacific Northwest. In: Coates, D. R., ed. Geiomorphology and engineering. Stroudsburg, PA: Dowden, Hutchinson and Ross; 1976: 199-221.

Thompson, K. Determining stream flows for fish life. In: Proceedings, instream flow workshop; 1972 March 15-16; Vancouver, WA. Vancouver, WA: Pacific Northwest River Basin Commission; 1972: 31-50.

Thorup, J. Substrate type and its value as a basis for the bottom fauna communities in running waters. Pittsburgh, PA: University of Pittsburgh, Pymatuning laboratory of Field Biology; Special Publication 4: 59-74; 1966.

Tiedemann, A. R.; Conrad, C. E.; Dieterich, J. H. [and others]. Effects of fire on water. Gen. Tech. Rep. WO-10. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979.

Toews, D. A. A.; Brownlee, M. J. A handbook for fish habitat protection on forest lands in British Columbia. Vancouver, BC: Department of Fisheries and Oceans; 1981. 173 p.

Wood, J. F. The aquatic insects of Rainy Creek with special reference to caddisflies (*Trichoptera*). Ellensburg, WA: Central Washington University; 1977. 71 p. Thesis.

Yee, C. S.; Roelofs, T. D. Planning forest roads to protect salmonid habitat. In: Meehan, W. R., tech. ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. Gen. Tech. Rep. PNW-109. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest And Range Experiment Station; 1980. 26 p.

11

Deer and Elk

Gary W. Witmer
Mike Wisdom
Edmund P. Harshman
Robert J. Anderson
Christopher Carey
Mike P. Kuttel
Ira D. Luman
James A. Rochelle
Raymond W. Scharpf
Doug Smithey

Table of Contents

Introduction

Black-tailed deer and Roosevelt elk, two common inhabitants of the forest lands of western Oregon and Washington, receive much public attention. These species represent a valuable recreational resource—both to hunters and those wishing to view the animals in a forest setting (fig. 1).

Much of the historic Roosevelt elk and black-tailed deer range is now managed for the intensive production of wood products. Forest management activities affect forest wildlife habitats on a broad scale, with patterns of forage and cover being changed significantly and frequently (Starkey et al. 1982).

In western Oregon and Washington, the management of commercial forest land is progressing rapidly, with conversion of virgin forest to intensively managed second-growth forest. During the early period of this conversion, clearcut logging created new foraging areas adjacent to the excellent cover conditions offered by the virgin forest. With the increased protection provided by fish and wildlife management agencies, deer and elk populations responded to the improved habitat by greatly increasing in numbers. Rapid cutting of the virgin forest and accelerated development of second-growth forests, however, led to large acreages of young conifer forest cover with limited forage production. While there has been much geographic variation in this pattern, the overall result has been a decline in deer and elk populations (Brown 1961, Taber and Raedeke 1980a, 1980b). Biologists often refer to this as the "boom and bust" phenomenon because neither the forage nor the cover needed to support large deer and elk populations is sustained over time.

Until recently, the effects (i.e. benefits or liabilities) of forest management on deer and elk were for a large part unintentional. A forest managed intensively for wood products, however, also can be managed to provide sustained quality habitat for deer and elk. This will only occur with a coordinated and interdisciplinary approach to forest mangement (Thomas et al. 1979).

Figure 1.—Roosevelt elk are common inhabitants of the forested areas of western Oregon and Washington.

Figure 2.—The managed forests of western Oregon and Washington are the primary habitats of black-tailed deer.

This chapter discusses the relationships of black-tailed deer and Roosevelt elk with forest habitats, especially as influenced by silvicultural practices. Practices for habitat improvement are discussed and a procedure outlined for use in developing forest management plans that considers the needs of deer and elk (fig. 2). Finally, some forest management options that reflect the needs of deer and elk are provided for the forest manager to consider when implementing silvicultural practices.

Although deer and elk are included in the term "big game," differences exist between the species in size, physiology, social organization, behavior, and habitat use. There also is variability in patterns of habitat use between individual populations of each species, reflecting the substantial climatic and geographic variability within the range of these species (fig. 3). When possible, habitat should be evaluated separately for each species, although in general, habitat meeting the requirements of elk also will provide for deer.

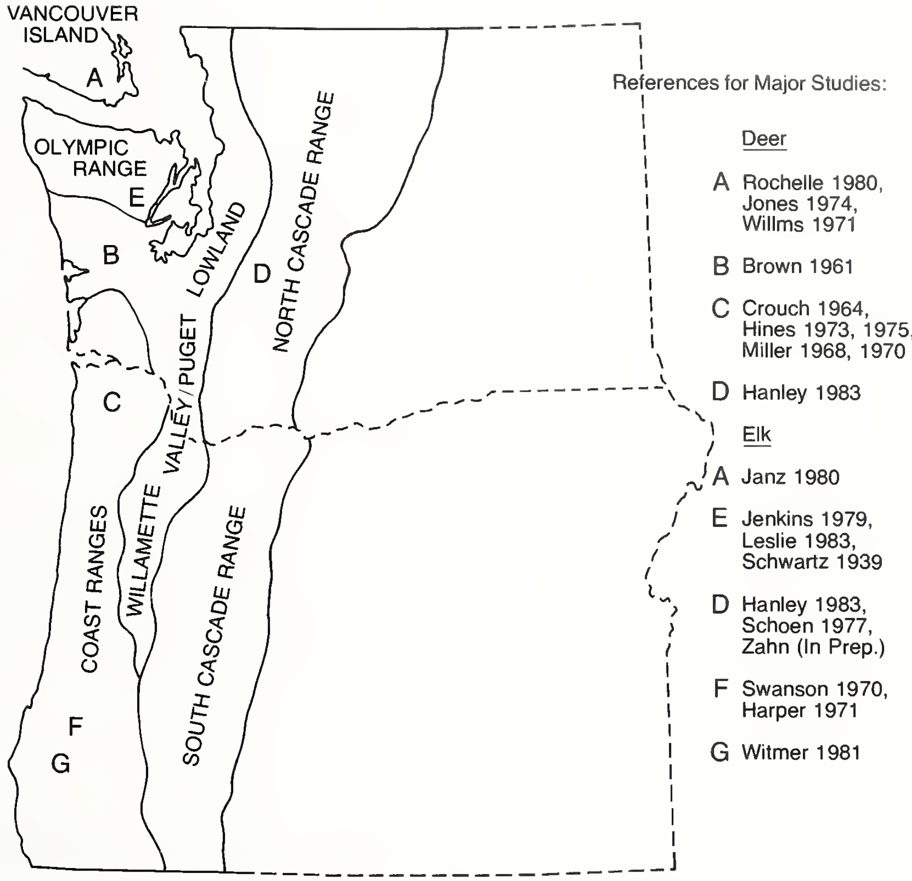


Figure 3.—Geographic regions (adapted from Bard 1973) and sites of major deer and elk studies within the range of black-tailed deer and Roosevelt elk.

Most of the data available on deer and elk habitat use came from studies (fig. 3) conducted during the conversion of virgin forest. Consequently, caution must be used when extending the data to situations involving forest stands being intensively managed on specific rotations. Despite these difficulties, a substantial contribution can be made towards the integration of deer and elk management within an intensive forest management regime. Indeed, such efforts are essential if current populations of deer and elk in western Oregon and Washington are to be maintained or expanded in the future (fig. 4).

Figure 4.—The harvest and management of the timber resource is the major factor affecting deer and elk habitat.

Habitat Relationships

Assumptions

This chapter is based on the following assumptions. They are derived from the literature and the professional experience of the authors.

1. Since the land base on which timber and wildlife are produced is the same, coordination of management activities is needed in order to obtain a sustained production of both products.
2. Forage and cover, and their distribution in time and space are the primary factors that limit black-tailed deer and Roosevelt elk populations.
3. Deer and elk management includes habitat manipulation and regulation of human activities.
4. Deer and elk habitat consists primarily of forage areas and three types of cover—each of which is structurally definable and quantifiable.
5. Productive habitat requires a quantity, quality, and arrangement of components that maximize energy acquisition and reduce energy use by deer and elk.
6. Vehicular traffic or other use of roads adversely affects adjacent habitat use by deer and elk.
7. Units for the management of deer and elk habitat should be comparable to the animals seasonal home range. For elk this ranges from 1,000 to 6,000 acres and usually encompasses a third- or fourth-order stream drainage. Deer home ranges are smaller, ranging from 320 to 640 acres.

In this section, the basic habitat components important to deer and elk are defined and discussed. Deer and elk, like other animals, require space, water, food, and cover. Management units with areas of high quality forage and cover distributed to permit full use, with reasonable freedom from human disturbance, provide the most productive habitat for deer and elk. For information beyond that presented here, readers are referred to the extensive reviews of the ecology and management of elk by Thomas and Toweill (1982) and of deer by Wallmo (1981).

Space

Deer and elk require an area of adequate size to carry out their daily activities of feeding, resting, and traveling, as well as annual production activities including breeding, giving birth, and raising young. Roosevelt elk are social animals, occurring in herds of various sizes. During a given season, a herd will use an area of 1,000 to 6,000 acres. The area required is smaller in energy-rich areas and larger on poorer sites (Jenkins and Starkey 1982). Black-tailed deer, on the other hand, occur as scattered individuals or small family groups. Within a particular season they use an area of about 320 to 640 acres.

Roosevelt elk and black-tailed deer populations inhabit regions of diverse physiography and climate. Those of the coastal region find relatively gentle topography and mild climate with abundant winter rainfall due to maritime influences. In the Coast Ranges, deer and elk are faced with more precipitous topography, with summers becoming warmer and drier from north to south. Winters with deep snowpacks are infrequent. In the Cascade and Olympic Ranges, deer and elk occupy regions of diverse topography with summers that range from mild in the north to hot and dry in the south. Winters frequently have deep snowpacks.

For the nonmigratory deer and elk of the coastal region, Coast Ranges and foothill areas of the Cascade and Olympic Ranges, summer and winter ranges are synonymous. A drainage basin in these areas should provide for both the summer and winter energy requirements of the animals.

In the higher elevation areas of the Cascade and Olympic Ranges many deer and elk populations show migratory patterns. During the summer they occupy energy-rich, high elevation areas, but winter snows force them to lower elevations where conditions are more favorable for conservation of the energy they stored during the summer. The areas where these animals winter will vary by aspect, elevation, and snow depth. Wintering areas should be determined by on-site inspection with recognition that boundaries will change with weather and time. The well-being of the population will depend on availability of adequate forage and cover on the summer and winter range to meet annual energy requirements.

Food, Cover, and Water

Deer and elk fulfill food and cover requirements within the forest ecosystem. From forage, deer and elk obtain the energy they need to maintain a constant body temperature, grow, perform daily activities, accumulate energy reserves, and reproduce. Cover is used to conserve energy acquired from foraging. Without cover, deer and elk may be exposed to adverse weather or the disturbing influence of potential predators (human and nonhuman). Both factors cause deer and elk to expend more energy. Although topographic relief can provide some shelter and protection from disturbance, the needs of deer and elk for cover in western Oregon and Washington are met primarily by forest vegetation in various seral stages (fig. 5). Baile and Forbes (1974), Blaxter (1962), and Moen (1973) provide general reviews of energy acquisition, use, and conservation by deer, elk, and other ruminants.

Most animals require water on a daily basis. July, August, and September are generally the driest months in western Oregon and Washington and during this period deer and elk may concentrate their use around wetlands or in riparian areas (see chapter 4) (Happe 1983, Schoen 1977).

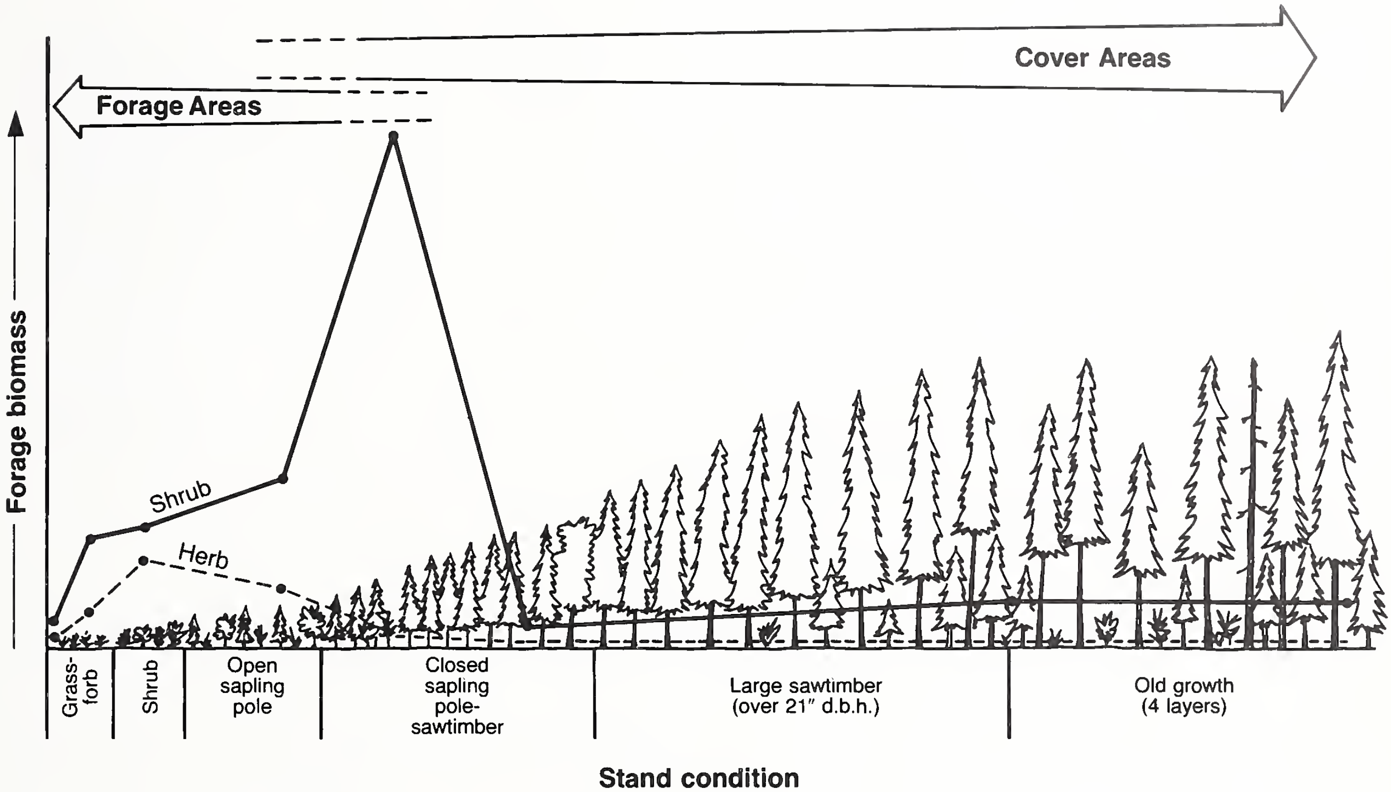


Figure 5.—Relationship of forest stand condition (or seral stage) with deer and elk forage and cover areas (biomass curves adapted from Long 1976).

Deer and elk must have both forage and cover within their normal home range if they are to acquire and conserve the energy they need on a daily basis. Management units without adequate forage areas are forage limiting while areas without adequate cover are cover limiting. A forage to cover ratio that is maintained over time will provide stable deer and elk populations.

Historically, deer and elk used naturally-occurring forest openings—those associated with meadows, river systems, and areas where disturbance such as fire, windthrow, or disease had opened the forest canopy (Bailey 1936, Jenkins and Starkey 1980, Leslie 1983). In the managed forest, deer and elk also use forage created by clearcut logging of units adjacent to forest stands (fig. 6) (Hanley 1983, Swanson 1970, Willms 1971, Witmer 1981).

Figure 6.—Clearcutting in small units can create a good balance of forage and cover for deer and elk.

Forage areas near cover are preferred because: 1) animals can quickly enter cover to escape predation or harassment and 2) less energy is expended in traveling to and from cover. On the other hand, it appears that deer and elk enter a forest stand the minimum distance necessary to provide: 1) suitable thermal conditions, and 2) bedding areas with escape routes from humans and predators (fig. 7).

Investigators have found less use near the immediate boundary of an opening and a forest stand (fig. 7), probably because forage plants are shaded by the trees and the edge of the forest stand does not provide adequate protection from adverse weather or predators.

The productivity of a drainage basin as deer and elk habitat is related to the amount of forest/opening edge. For example, several small cutting units distributed throughout the drainage basin, will provide more forest/opening edge than a few large units with the same acreage. This has important implications as to the size, shape, and placement of harvest units in the managed forest (fig. 8, A and B).

The optimum spacing of forage and cover areas may not be a strictly mechanical function. Benches, slopes, aspect, and other factors will influence animals to select one area over another with the same type of cover or forage. For example, areas of less than 50 percent slope generally receive greater use by deer and elk (Harper and Swanson 1970, Miller 1968, Schoen 1977, Witmer 1981).

Specific definitions of forage areas and of forest cover types are given in the next two subsections. Although gradients exist between forage and cover as well as between different cover types, habitat evaluation procedures and subsequent management require definitions that artificially reflect distinct breaks between forage and/or cover types. Overlaps exist and many stand conditions can serve multiple functions. Also presented is information concerning the size and quality of forage and cover areas.

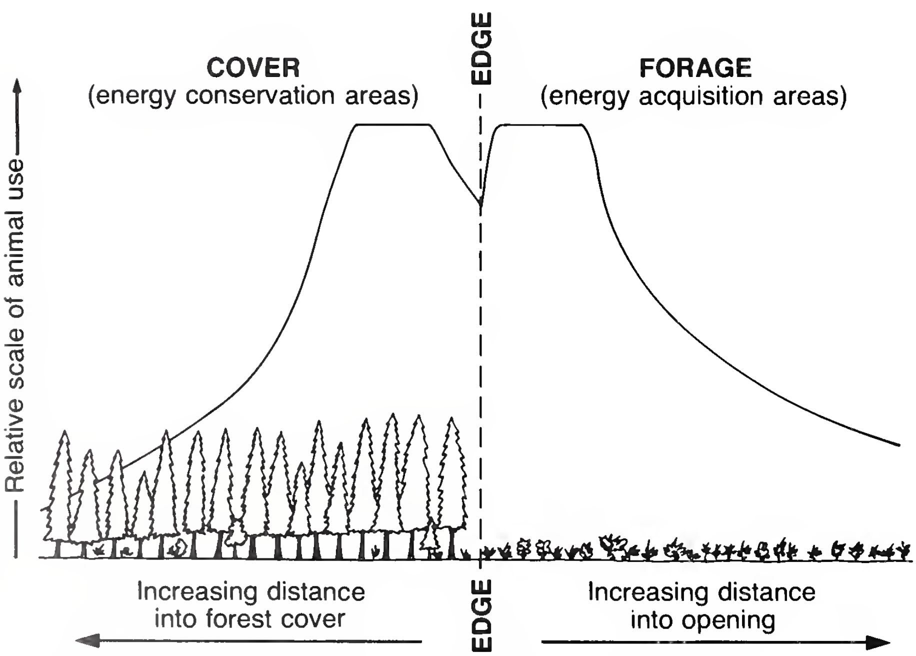


Figure 7.—Generalized relationship of deer and elk habitat use as measured from edge (derived from Hanley 1983, Harper and Swanson 1970, Willms 1971, Witmer 1981).

Forage Areas

Forage areas are defined as vegetated areas with less than 60 percent combined canopy closure of tree and tall shrub (greater than 7 feet in height). This includes the grass-forb, shrub, and open sapling-pole stand conditions and may include some older stands that have been thinned. In a managed forest the primary forage areas are those that have had all or most of the forest canopy removed, i.e. clearcut or shelterwood units.

Within forage areas, both forage quantity (fig. 5) and quality are higher than in other stand conditions because the ground vegetation receives more sunlight and does not have to compete with trees for minerals and water (Jameson 1967, Krueger 1981). Stands that are not thinned to less than 60 percent crown closure or where the canopy closes rapidly after thinning, do not provide much forage (Witler 1975).

The results of several studies using pellet group counts, direct observation, and radio telemetry locations, were used to conceptualize the "forage-area-size-to-use" relationship presented in figure 8. In general, forage area use starts to decline about 200 feet from edge and declines rapidly at 400 to 600 feet from edge. Studies by Hanley (1983), Merrill et al. (1983) and Willms (1971), however, have shown that in the absence of human disturbance, both deer and elk will use larger forage areas. Other factors that influence the size of area used are the availability of succulent forage (Hanley 1982), the season of the year, the topography, and the number of animals using the forage area (Harper and Swanson 1970, Witmer 1981). With seasonal reductions in forage availability, or increasing competition for forage, animals will range further from cover.

Three main factors--canopy removal, ground disturbance, and forage seeding with fertilization--influence the quantity and quality of forage on forest units. Clearcutting results in a substantial increase in the quantity and quality of understory forage. Shelterwood cutting also improves forage, but not as much as clearcutting. After removal of the overstory, forage quantity and quality is usually further enhanced by disturbance (such as scarification) or burning (Harper

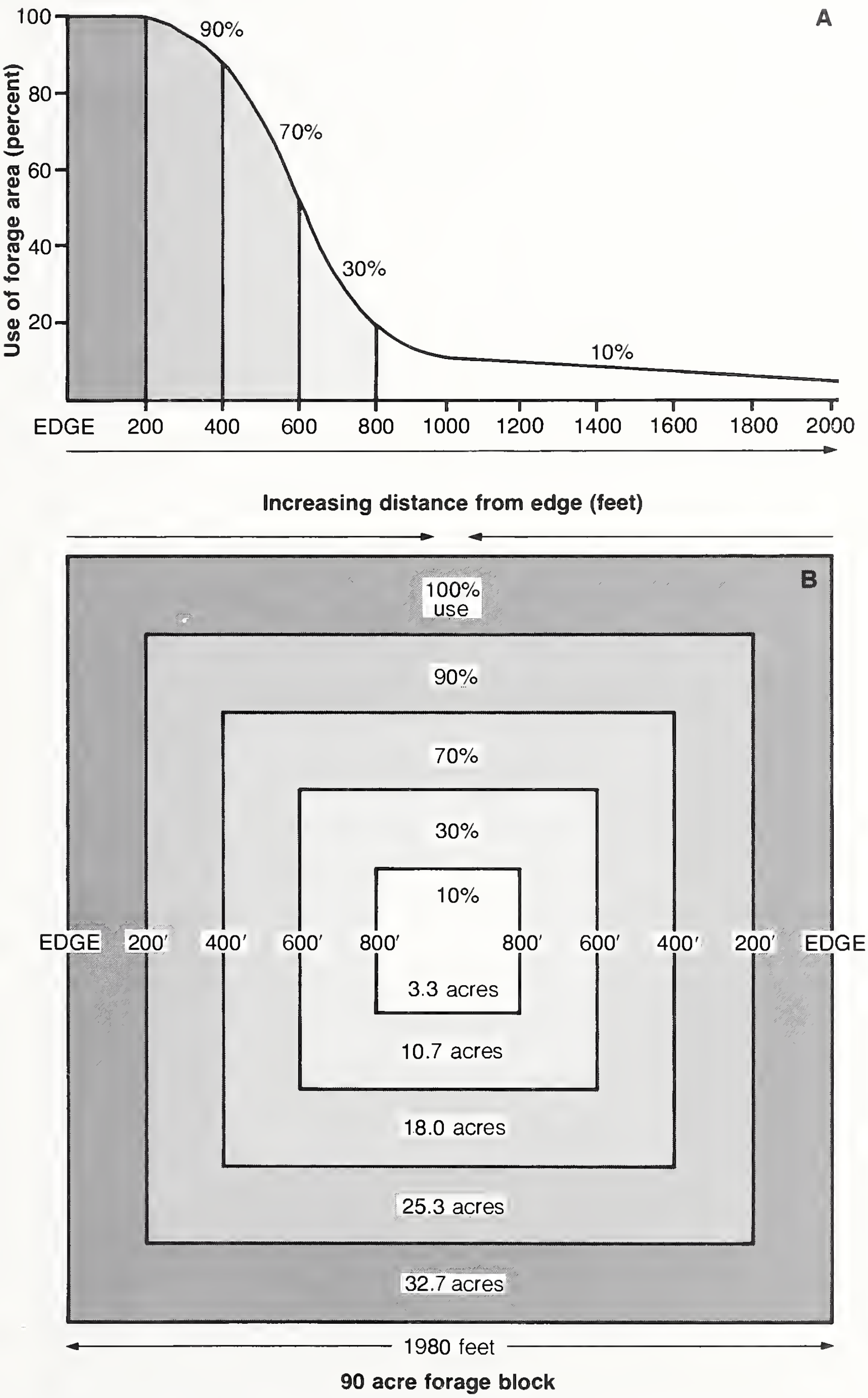


Figure 8.—The generalized influence of distance to edge on deer and elk use of forage areas (derived from Hanley 1983, Harper and Swanson 1970, Willms 1971, Witmer 1981).

1971, Taylor and Johnson 1976). Finally, seeding of forage species and fertilizing of both native and seeded species can substantially increase forage quantity and quality (Campbell and Evans 1978, Mereszczak et al. 1981, Taylor and Johnson 1976). For more detailed information see the sections on the influence of silviculture and habitat improvement.

Cover Areas

Cover areas are important to deer and elk because of modifications the cover makes in microclimates. In cover the animals are less subject to extremes in temperature, solar radiation, windspeed, humidity, rain throughfall, and snow accumulation (Geiger 1965, Lee 1978). In addition, cover reduces the potential for predation and human disturbance.

In order to survive, deer and elk must maintain a favorable balance between energy input (from foraging) with energy use (from activity and body temperature maintenance). When highly nutritious forage is available, animals will spend less time in cover. When the quality or availability of forage declines or weather conditions become extreme in the foraging areas, animals move to protective cover to conserve the energy already stored in body reserves. The importance of the forage component in protective cover increases in direct proportion to the length of time the animals are forced to use this cover.

Restricted human disturbance and the availability of nutritious forage may partially compensate for a lack of cover, whereas good cover may partially compensate for poor quality forage (Peek et al. 1982). In portions of the Mount St. Helens blast zone where human disturbance is restricted, low but increasing densities of elk are using natural revegetation, as well as seeded and fertilized areas, far from cover (Merrill et al. 1983). Whether animals using the interior portions of the blast zone can survive if they remain there during a severe winter is doubtful, and whether they will continue to use the area if human disturbance increases has not been determined. In any case, deer and elk use of the area will decrease in a few years as the high-quality foraging conditions are replaced by extensive young forest cover. Ideally, deer and elk habitat would consist of a

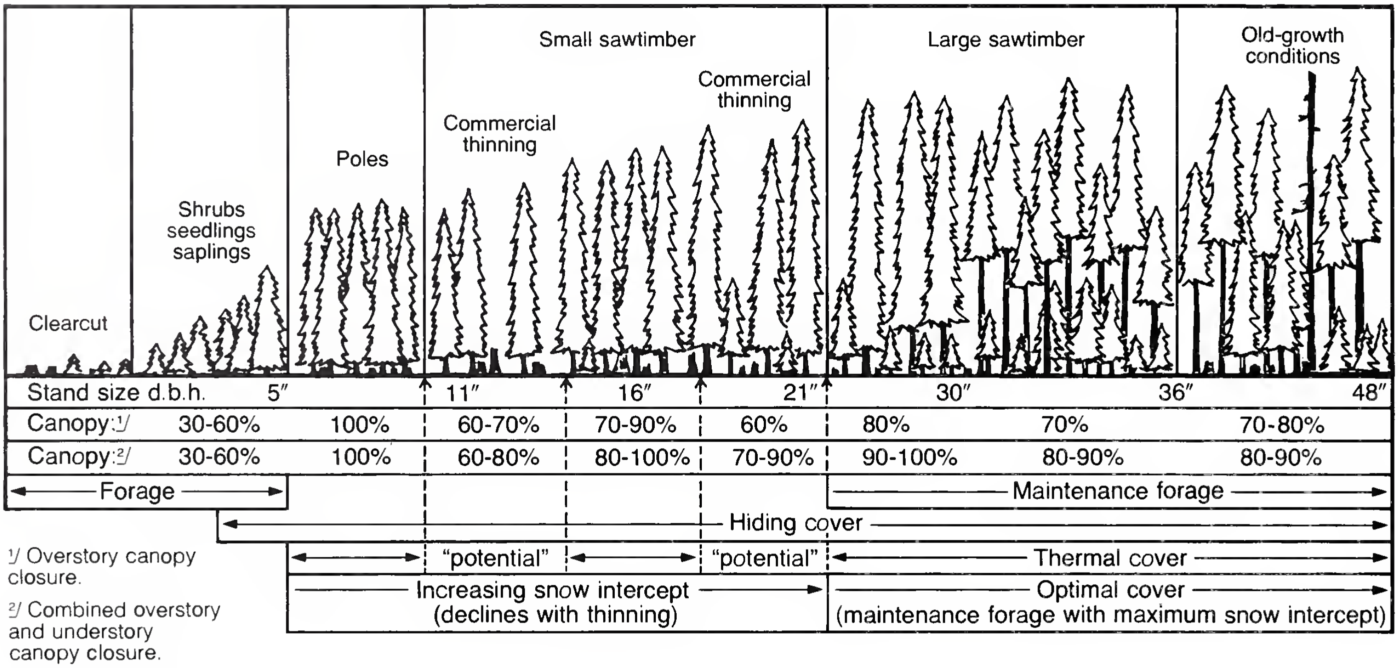


Figure 9.—Deer and elk habitat conditions illustrating the relationship of described cover types to stand size and age.

balance of high quality forage and high quality cover areas. A balanced mix of habitats would be expected to maintain higher densities of elk and deer through time.

Normally in western Oregon and Washington, deer and elk conserve energy by using forest cover until favorable weather or the absence of disturbance again allows them to use energy-rich forage areas. Three distinct types of cover are recognized: hiding, thermal, and optimal cover. They provide three distinct functions for deer and elk: 1) visual screening from disturbance; 2) a more favorable thermal regime, both winter and summer, than occurs in forest openings; and 3) snow interception resulting in reduced snow depths, and maintenance forage to sustain the animals during periods of heavy snowfall. The older the forest stand, the more cover functions it provides. A very young stand provides only hiding cover, whereas mature and older forest stands may provide hiding, thermal, and optimal cover (fig.9).

Hiding cover is defined as any vegetation capable of hiding 90 percent of a standing adult deer or elk at 200 feet or less (adapted from Thomas et al. 1979). This includes some shrub stands and all forested stand conditions with adequate tree stem density or shrub layer to hide animals. In some cases, topographic features also can provide hiding cover.

When hiding cover provides a visual screen, deer and elk can spend more time foraging or resting and less energy fleeing from human disturbance or predators (fig. 10). On westside forest lands, most stands from the open sapling-pole to old-growth conditions provide hiding cover unless they recently have been heavily thinned.

Thermal cover is defined as a forest stand that is at least 40 feet in height with tree canopy cover of at least 70 percent. These stand conditions are achieved in closed sapling-pole stands and by all older stands unless the canopy cover is reduced below 70 percent. Deciduous stands may serve as thermal cover in summer, but not in winter.

A stand structure that provides thermal cover reduces energy expenditures by modifying the adverse effects of weather (Moen 1973, Moen and Stevens 1970, Robbins 1983). Deer and elk use thermal cover to modify the effects of weather during both winter and summer. In

Figure 10.—Hiding cover protects animals from disturbance and predation.

thermal cover the animals are most likely to find a favorable microclimate, or what animal physiologists refer to as the "thermal neutral zone" (Blaxter 1962, Leckenby 1977, Mount 1974).

Miller (1970) found that deer would usually leave foraging areas for thermal cover when temperatures dropped below 20°F or rose above 60°F (fig. 11). Zahn (pers. comm.), working in the Cedar River watershed in Washington, found that elk would leave clearcuts for thermal cover when solar radiation exceeded 50 percent of maximum, or about 10 A.M. on clear days, especially during the hot summer months. Zahn also observed that elk seek the thermal protection offered by old-growth stands over that of second-growth stands under these conditions. Observations of elk in southwest Oregon indicate they follow a similar pattern during hot summer weather.

Figure 11.—Second-growth stands provide thermal cover but little forage. Forage can be enhanced by commercial thinning.

Thinning the stand to less than 70 percent canopy cover will reduce the stand's ability to function as thermal cover, but the canopy will again close within a few years (Edgerton and McConnell 1976). Such stands may be classified as "potential thermal cover" until the canopy again exceeds 70 percent.

Optimal cover is defined as a forest stand with: 1) four layers (overstory canopy, sub-canopy, shrub layer, and herbaceous layer); and 2) an overstory canopy which can intercept and hold a substantial amount of snow yet has dispersed, small (<⅛ acre) openings. These criteria are generally achieved when the dominant trees average 21 inches d.b.h. or greater, have 70 percent or greater crown closure, and are in the large sawtimber or old-growth stand condition.

This type of cover is called "optimal" because, in addition to providing hiding and thermal cover functions, the shrub and herbaceous layers along with lichens and litterfall, provide supplemental forage during prolonged periods of adverse weather (i.e. periods of deep snow) (fig. 12). Snow depths of 1½ or more feet impede deer and elk movement (Harestad and Bunnell 1979) and bury most forage in forest openings (Crouch 1964). The overstory (dominant and codominant trees) of optimal cover will prevent snow depths within the stand from exceeding 1½ feet in most winters.

Because the overstory canopy is high above the ground and has less than 100 percent coverage, some sunlight reaches the forest floor, resulting in a better developed herbaceous and shrub layer than in young dense stands. Lower level limbs of the sub-canopy (6 feet or less above the ground) give additional thermal regulation during cold periods by reflecting body heat back to the animals. Numerous investigators have found that, when available, Roosevelt elk and black-tailed deer select optimal cover during adverse weather periods (Harper and Trainer 1969, Janz 1980, Jones 1974, Newman 1956).

There also is an increase in the energy demands of deer and elk during hot, sunny, summer weather as they seek to reduce the build-up of excessive body heat. During periods of high temperatures and intense solar radiation, studies have shown that elk use optimal cover (Witmer 1981, Zahn, pers. comm.) while deer seek out stands with a complex secondary structure (that is, a well-developed shrub and understory layer) (Happe 1983).

Figure 12.—Optimal cover provides thermal protection from heat and cold, snow intercept, and maintenance forage.

Figure 13.—Cover blocks close to forage areas that are large enough to moderate weather conditions will receive the heaviest use by deer and elk.

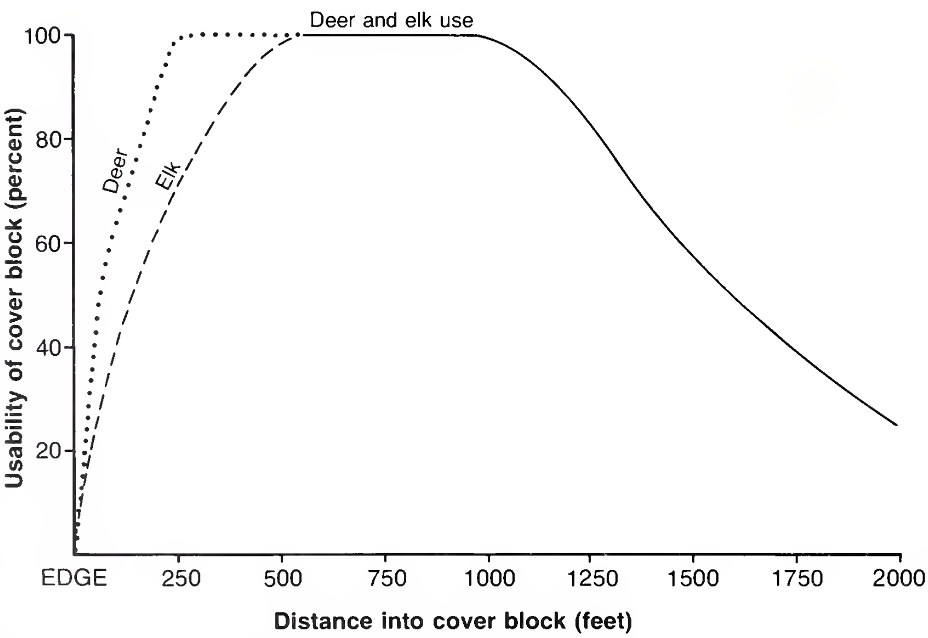


Figure 14.—The influence of distance to edge on deer and elk use of cover blocks (adapted from Hanley 1983, Willms 1971, Witmer 1981).

The size of a cover stand, its structure, and the availability of suitable bedding areas, determine how the stand will be used by deer and elk. The interior of large stands of thermal or optimal cover will not be used as fully as smaller stands because of the distance the animals must travel to forage areas. Conversely, small cover blocks will be used less because they are less able to modify microclimate (Franklin, J.F.; pers. comm.), and less able to provide favorable thermal areas for bedding (fig. 13). The results of several studies using pellet group counts and radiotelemetry locations were used to determine the "cover-block-size-to-use" relationships presented in figure 14.

Roads and Disturbance of Deer and Elk

Forest roads are constructed to harvest forest stands and, once in place, are maintained to manage regenerating stands and provide access for fire protection (fig. 15).

Intensively managed forests require well developed road systems. These roads often are characterized by: 1) public accessibility; 2) little screening cover along edges; 3) wide rights-of-way with steep, high cut banks; and 4) location adjacent to or passing through riparian habitat.

The increased traffic volume on forest roads resulting from public access can disturb or harass deer and elk, increaseing their metabolic rate and use of energy resources needed for normal growth and reproduction (Geist 1978). Deer and elk use of otherwise suitable feeding and resting areas may be reduced because of disturbance (Lyon and Basile 1980), and use of some habitats for breeding and giving birth may be precluded (Roberts 1974). Legal and illegal hunting from roads may increase causing portions of the population to be over-harvested (Leege 1976).

The degree of impact from roads and their associated traffic on habitat use by black-tailed deer and Roosevelt elk was reported by Willms (1971) and Witmer (1981), respectively. Their results, based

upon pellet group counts and radiotelemetry locations, were similar to the results reported for Rocky Mountain elk (Lyon 1979, Pederson et al. 1980).

Figure 15.—Road networks subject to frequent use can disrupt deer and elk use of forage areas.

Witmer (1981) found elk use of areas within 400 feet of primary roads and within 200 feet of secondary roads, to be significantly less than expected. Primary roads provide the main access to the managed forest and have high volumes of traffic. Secondary roads include feeder lines and deadend spurs leading to harvest units. They are little used roads with a low frequency of traffic. The majority of road mileage on managed forest land is in secondary roads. The general influence of increasing road network density on deer and elk habitat use is illustrated in figure 16.

Roads that are closed to vehicular traffic do not result in significant disturbance of deer and elk. In fact, they often are used for foraging, bedding, and as travel lanes (Willms 1971, Witmer 1981). Regular ongoing use of roads for forest management activities seems to be less disruptive than the pattern of intermittent use associated with hunting, wildlife viewing, and other recreational activities.

Special Habitats

Deer and elk make greater use of certain forest habitats during the course of their daily and seasonal activities. These habitats should receive special consideration in forest management because of their importance to deer and elk. These productive and diverse habitats are special to deer and elk because they: 1) occupy a relatively small portion of the forest (i.e. riparian habitat and natural openings); 2) occur in dwindling acreage as forest management intensifies (i.e. old-growth habitat); or 3) have a combination of characteristics that meet the special requirements of deer and elk (i.e. breeding, calving, and fawning habitat).

Riparian Habitat

Riparian vegetation (see chapter 4) along rivers, larger streams, lakes, and ponds, provides water, forage, shade, and travel corridors for many species of wildlife (Luman and Neitro 1980). Studies have shown deer and elk also make greater use of this vegetation especially during calving/fawning periods, dry summer months (Happe 1983, Witmer 1981), and winters of heavy snowpack. The width or type of vegetation needed to maintain the integrity and value of riparian habitat for deer and elk has not been thoroughly investigated. Riparian buffer zones, however, should be wide enough and with vegetation tall enough to give the animals protective cover while using this type of habitat (Hynson et al. 1982).

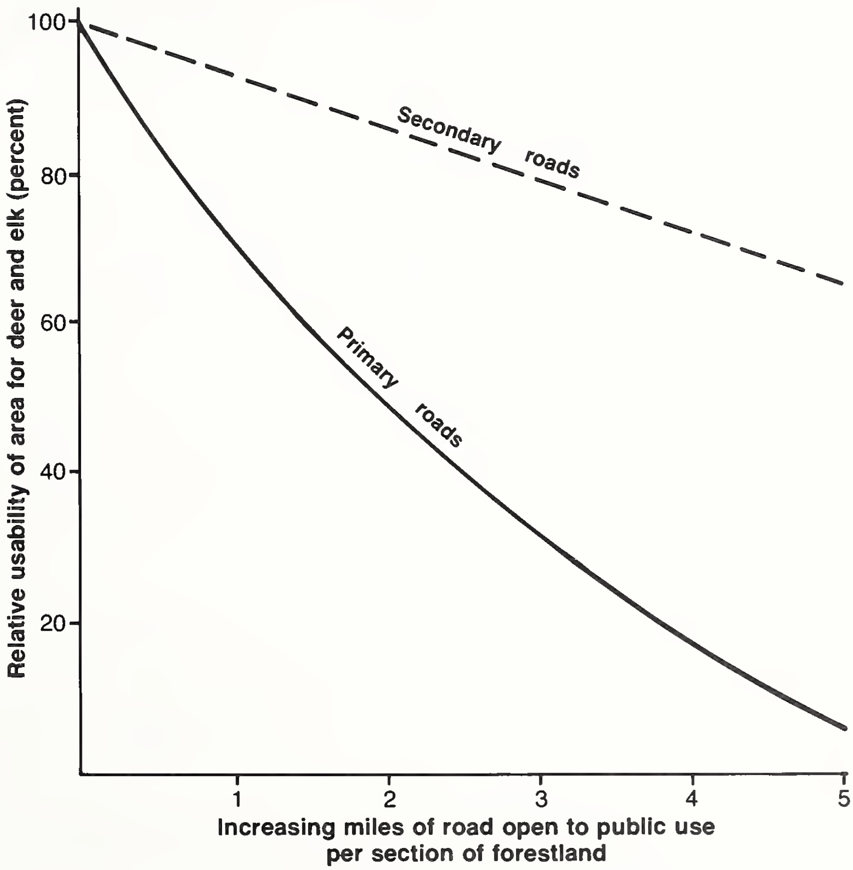


Figure 16.—Generalized influence of increasing open road density on otherwise usable deer and elk habitat (derived from Willms 1971, Witmer 1981).

Natural Openings

Natural openings, such as grassy slopes, wet meadows, floodplains, and swamps, occur in the forest. On these sites, the primary vegetation is grasses, forbs, and shrubs with scattered trees. Historical records suggest that Roosevelt elk and black-tailed deer were commonly associated with these openings (Bailey 1936). Natural openings are important to deer and elk because: 1) they provide nutritious forage species that rarely occur in the coniferous forest; and 2) they provide an inherent habitat edge that enhances deer and elk use. Wet meadows are used extensively by elk as forage areas, wallows, and as centers for harem collection and rutting activity (fig. 17).

Figure 17.—Natural openings in the forest are important habitat features for deer and elk.

Old-growth Habitat

Several studies (Janz 1980, Pedersen et al. 1980, Witmer 1981, Zahn [In Prep.]) have shown that elk will select residual old-growth forest stands for cover in preference to adjacent young second-growth stands throughout the year. These stands are especially important to deer and elk during periods of deep snow (Jones 1974, Taber and Hanley 1979) because they provide cover with maintenance forage (i.e. optimal cover). Hanley (1982) also noted a late summer shift in foraging behavior to this type of habitat as succulent vegetation in open clearcuts dried up.

On the commercial forest lands of western Oregon and Washington these old-growth stands are rapidly being liquidated (Juday 1977, Meslow et al. 1981). Therefore, this unique and preferred habitat type will require special consideration during the conversion of virgin forests if it is to serve as a component of Roosevelt elk and black-tailed deer habitat now and in the future (Franklin et al. 1981, Taber and Raedeke 1980a and 1980b).

Calving and Fawning Habitat

Successful reproduction is essential to the continued growth or maintenance of deer and elk populations. Components of prime calving/fawning areas include quality forage, water, areas relatively free of slash, gentle warm slopes, and cover for protection from inclement weather or disturbance (Harper 1971, Hines 1975, Janz 1980, Washington Game Department 1974, Witmer 1981).

Influence of Silviculture

In an intensively managed forest, silvicultural practices, their timing and extent will be factors in determining the productivity of that forest as deer and elk habitat (fig. 18) (Bunnell and Eastman 1976, Lemos and Hines 1974, Taber et al. 1981). The timber cutting patterns of the past 50 years or more have created much of the deer and elk habitat that occurs today in managed forests in western Oregon and Washington. Similarly, current harvesting patterns will determine the productivity of forest habitat for deer and elk for decades to come (Brown 1961).

The number of forage and cover areas, their size, quality, and position relative to one another will be primary influences. Human use of road networks established to manage the forest resource also will influence the productivity of deer and elk habitat (Lyon 1979).

Large mammals such as deer and elk have relatively large home ranges and their habitat often encompasses a variety of forest characteristics. Therefore, the impact of silvicultural practices applied to a particular area of deer and elk habitat should be evaluated in relation to the distribution and availability of other forage and cover types throughout the management area.

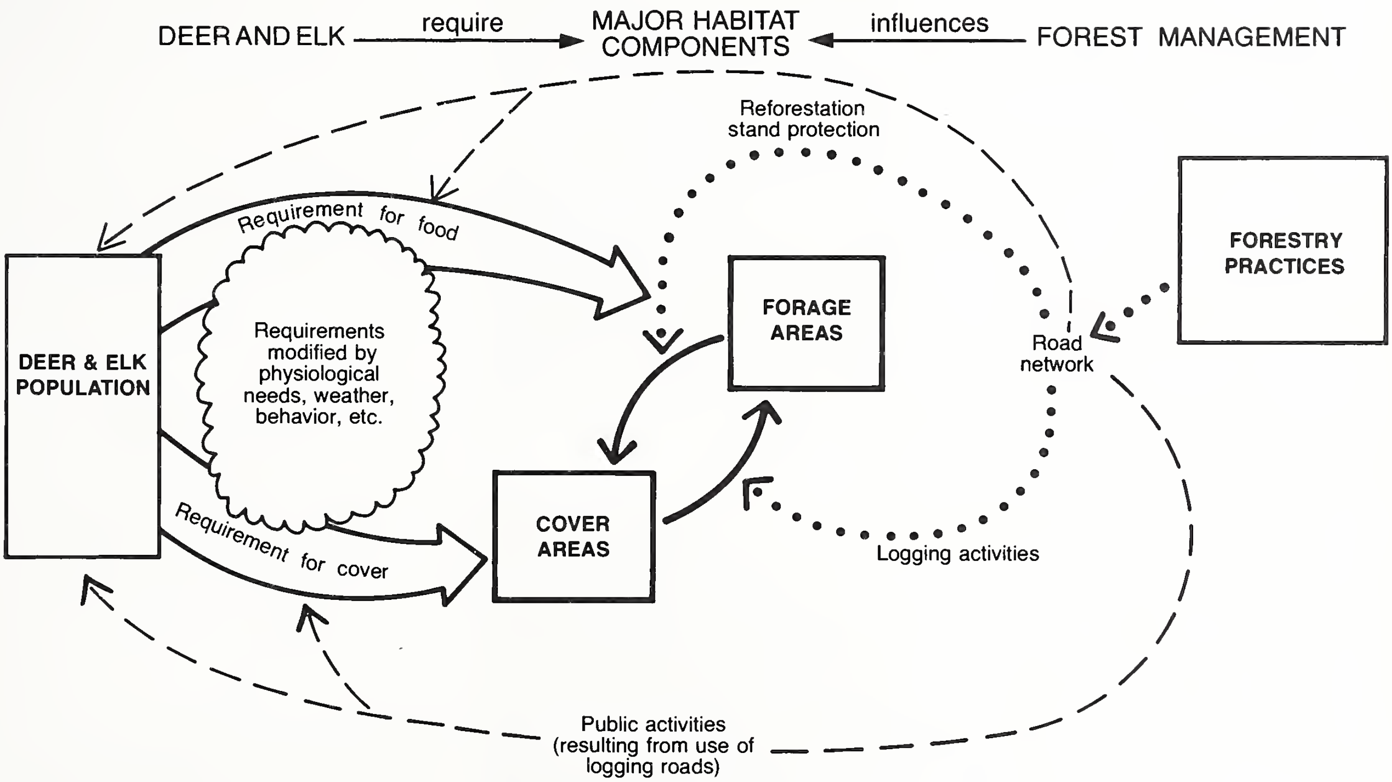


Figure 18.—The major direct (• • • •) and indirect (- - -) influences of forest management on deer and elk populations and major habitat components (———).

Silvicultural treatments commonly applied in western Oregon and Washington include clearcut harvest, site preparation, conifer regeneration, stand protection, control of competing vegetation, stocking control, and fertilization. Each treatment has specific effects on deer and elk habitat. Most treatments can have positive or negative influences depending upon their relationship to the particular stand or to stands within the deer and elk management unit and the time frame considered (fig. 19). The following briefly summarizes these effects on deer and elk habitat.

Harvest, Site Preparation, and Regeneration

Clearcut harvest of timber normally enhances forage conditions by creating openings in the forest and initiating plant succession from nearly bare soil conditions. The area no longer provides vegetative cover but has the potential for providing an increase in quantity and quality of forage. For a short period during logging and before slash removal, there is a lack of forage and animal use declines (Harper 1971). In a one to two year period, however, residual ground vegetation sprouts and new forage plants invade the unit resulting in a dramatic increase in forage accompanied by an increase in deer and elk use (Brown 1961, Crouch 1968, Rochelle and Bunnell 1979).

Small clearcuts distributed in both time and space provide a balance of forage and cover for deer and elk. The situation provides a large amount of habitat "edge."

Clearcutting of large areas results in high quantity and quality of forage but a deficiency of cover. Forage areas far from cover will not be fully used. Later in the successional pattern, forage will become deficient and cover abundant. At either time the amount of habitat "edge" will be low.

Figure 19.—Comparison of the effects of two clearcut harvest patterns on deer and elk habitat.

Several factors affect forage quality and the length of the period of high productivity of the area. Availability of forage is determined by the amount and distribution of slash and residual vegetation (Swanson 1970). Soil disturbance and burning of moderate intensity generally improves the unit as a forage area and extends its productive period by reducing residual shrub and tree cover and providing a suitable seedbed for invading herbaceous species (fig. 20) (Bunnell and Eastman 1976, Taber et al. 1981). Germination and growth of forbs and grasses are usually enhanced. Burning and scarification can vary in extent, being patchy to complete, with resulting differences in vegetative response within the site (Taber et al. 1981).

Herbicides often are used to reduce competition between conifers and such species as bigleaf maple, vine maple, red alder and grasses (Gratkowski 1975). The potential effects on the unit as a forage area can be positive or negative. Often there is an initial decline in forage quantity, followed by a sharp increase as forbs, grasses, and hardwoods sprout. Conifers, freed from competition, usually reclaim the unit more quickly, thus shortening its duration as a forage area. If dense shrub cover has dominated the unit, herbicide use may improve access and ground forage for deer and elk (Harper 1971).

In many areas, however, hardwoods are a preferred habitat type for elk and are heavily used in spring and summer (Witmer 1981). Under these circumstances hardwood conversion for conifer establishment may negatively impact elk production and special consideration should be given to retention of this habitat type.

Figure 20.—Burning slash created by timber harvesting improves access and the quality and quantity of forage for deer and elk.

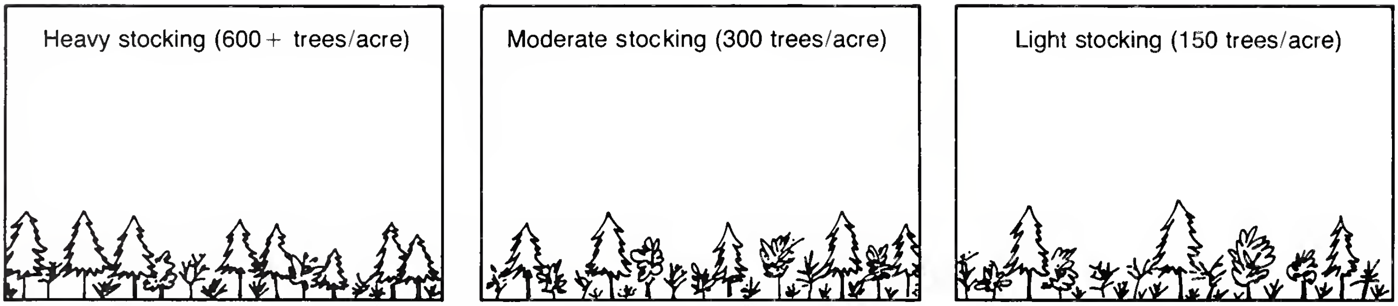
Significant improvements in nutrient quality, forage production and palatability result from forest fertilization (Rochelle 1979, Staneck et al. 1979). Growth of young conifer stands increases and, in combination with thinning, allows the development of understory vegetation (Jones and Stokes 1980). Areas fertilized with sewage sludge had significantly greater deer densities than unfertilized areas (West et al. 1981, Zasoski 1981). Timing, however, will determine the net impact of fertilization on forage. Fertilization to increase tree growth normally takes place when conifer canopies are beginning to close, or just after precommercial thinning. This enhances forage for the period before the canopy closes, but it also speeds the rate of closure. If significant benefit to deer and elk forage is also a goal, fertilizer applications designed to benefit young conifer tree growth should be applied 3 to 5 years before the conifer canopy closes.

Stocking Control

Conifer planting density will affect the productive period of the unit as a forage area: low planting densities will extend the period, whereas high densities will have the opposite effect (fig. 21) (Lemos and Hines 1974). Also, precommercial thinning will extend the time the stand remains in an open condition (Hungerford 1969, Taber and Raedeke 1980a and 1980b). Slash from precommercial thinnings, however, may reduce or preclude deer and elk access for several years (fig. 22). This impact on animal access can be lessened by thinning earlier when trees are smaller, or by removing or windrowing slash.

Commercial thinning can result in an increase in quantity and quality of understory forage. Previous stand conditions (i.e., extent of precommercial thinning, amount of understory vegetation) combined with the degree of commercial thinning, will determine the amount of forage produced (Witler 1975). For some

STOCKING RATES



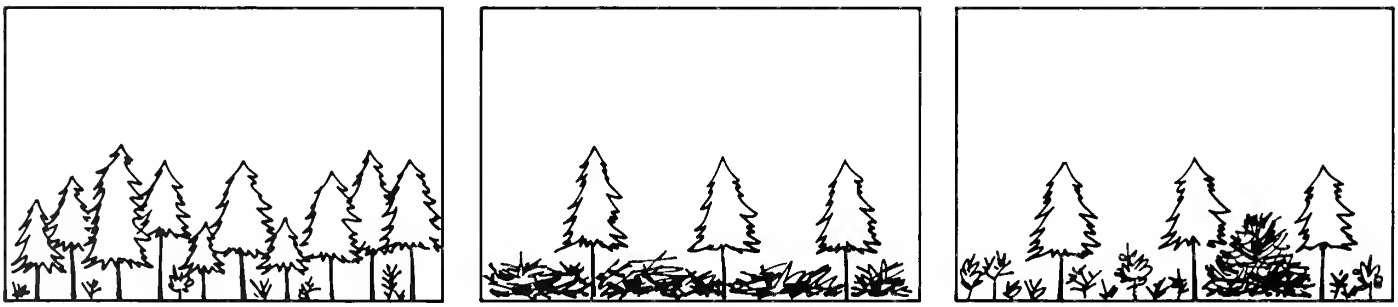
Heavy stocking:
Forage quality/quantity – fair
Forage duration – short
Canopy closure – rapid
(Most forage lost prior to precommercial thinning.)

Moderate stocking:
Forage quality/quantity – good
Forage duration – moderate
Canopy closure – moderate
(Some forage will survive to precommercial thinning.)

Light stocking:
Forage quality/quantity – good
Forage duration – long
Canopy closure – slow
(Precommercial thinning may be unnecessary. Some forage may survive through the entire rotation.)

Figure 21.—Generalized effect of conifer stocking rates on deer and elk, forage areas 6 to 12 years after clearcutting and reforestation.

PRECOMMERCIAL THINNING

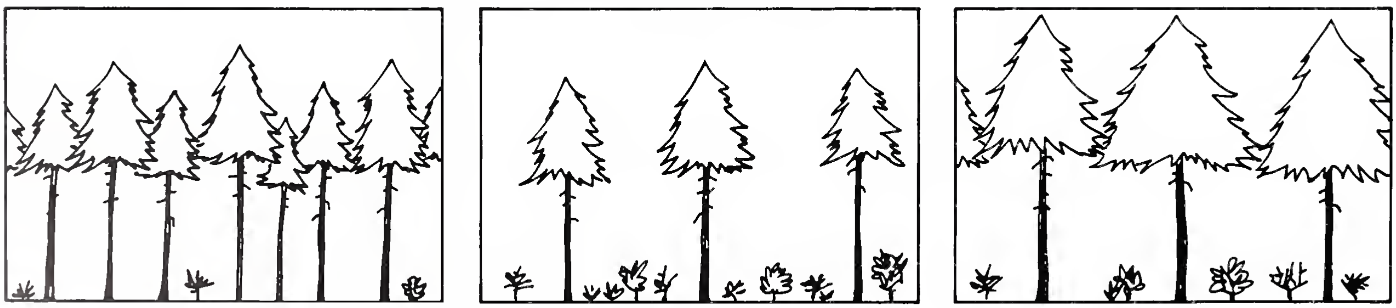


Unthinned with closed canopy
Forage – poor to fair
Access – good
Hiding cover – good

Thinned with no slash disposal
Forage – very poor to poor
Access – very limited
Hiding cover – poor

Thinned with slashed windrowed
Forage – good to very good
Access – good
Hiding cover – poor

COMMERCIAL THINNING



Unthinned with closed canopy
Forage – very poor to poor
Snow intercept – fair
Thermal cover – good

Thinned with open canopy
Forage – fair
Snow intercept – poor
Thermal cover – poor

Thinned with canopy closing
Forage – poor to fair
Snow intercept – fair to good
Thermal cover – fair to good

Figure 22.—Generalized effects of precommercial and commercial thinning on forage and cover for deer and elk.

years after thinning, however, the stand may not provide thermal or optimal cover conditions (Edgerton and McConnell 1976). A checkerboard pattern of thinning will allow increased forage production in some stands while nearby stands continue to provide for the cover requirements of deer and elk.

Stand Protection

Protection of conifer plantations from animal damage, unless the animals are totally excluded by fencing, will not significantly affect either forage or cover availability. Severe repeated browsing by deer and elk, however, can delay conifer establishment and extend the period before canopy closure (Black et al. 1979). This may extend the period of forage production while delaying the development of cover characteristics.

There are many techniques available to the land manager for improving forage and cover quality and availability to deer and elk. Several techniques can be implemented in conjunction with standard forest management activities, whereas others require additional effort.

Benefits to be realized by improving deer and elk habitat are:

1. Increased size and vigor of animals through improved nutrition and reduced energy expenditures;
2. Increased numbers of animals through higher recruitment and survival rates;
3. Dampened "boom and bust" cycles of animals by providing a balance of forage and cover through time on both summer and winter range; and
4. In some cases, incidence of browsing damage on conifers by deer and elk may be reduced by making more palatable forage available.

Forage Improvement

The manager can increase the quantity and quality of forage produced on existing forage areas and/or increase the area producing forage (Hanson and Smith 1970). Those areas where deer and elk will respond most positively to treatment and provide the best return from the investment are sites 1) with fertile soils, i.e., higher site class or index; 2) with slopes of less than 50 percent; 3) on winter range; 4) occupied by female animals during late pregnancy and while nursing; and 5) where human access is restricted.

Increase Forage Quantity and Quality

Seeding, planting and fertilizing of grasses, forbs, and shrubs on both openings (clearcuts and shelterwoods) and thinned stands within the forest can significantly increase forage quantity and quality for deer and elk. Species selection and preplanning of seeding/planting projects are very important for successful forage establishment in western Oregon and Washington (table 1).

Fertilization at the time of seeding/planting helps assure successful forage establishment. In addition, it can be used to improve native forage (Taylor and Johnson 1976) or increase crude protein, especially in seeded species such as orchard grass (Agpaoa 1981). It is important to use fertilizers customized to local soil conditions, and a soils scientist should be consulted. Fall applications of fertilizer will improve winter range and early spring forage, whereas spring applications will improve spring and summer forage (fig. 23). Fertilization may also influence the distribution patterns of deer and elk (Brown and Mandery 1962).

Table 1—Forage species of proven value for use in western Oregon and Washington

Forage species	References
Orchardgrass, ryegrass, white clover birdsfoot trefoil (wildlife mix no. 2)	Smith 1980
Perennial and annual ryegrass, orchardgrass, tall fescue, white and subterranean clover	Mereszczak et al. 1981
Catsear, hawksbeard, fleabane, hawkweed, phacelia and redstem fireweed	Campbell and Evans 1978 Campbell and Johnson 1981
Many species of grass, legumes, shrubs and trees, cereal grains, lupine, sedges	State of Oregon 1980 1/ State of Washington 1983 1/
Grasses, legumes	Cleary 1972

1/ An especially useful reference

Figure 23.—Application of fertilizer can benefit both native and seeded species.

Man-made openings in the forest can be managed to provide forage of high value to deer and elk. For example, Jewell Meadows in Clatsop County, Oregon, is being intensively farmed for elk use with a high level of success (Mereszczak et al. 1981) as is the Olympic Habitat Management Area in Grays Harbor County, Washington (Brown and Mandery 1962). Powerline rights-of-way are another example where encroachment by tree species is controlled by chemical, mechanical, or burning methods (Yoakum et al. 1980). Native understory vegetation is often supplemented with grass and forb seedings as a means of reducing encroachment of trees. These areas, especially when fertilized, are heavily used by deer and elk because of the proximity of high quality forage to the cover of adjoining forest stands (Bramble and Byrnes 1972, Taber et al. 1972).

Traditional farming methods can be used on level areas such as Jewell Meadows, but on most forest land seed and fertilizer must be broadcast via cyclone hand seeders or with power seeders mounted on helicopters, tractors, or trucks. Disturbed areas such as skid trails, landings, firelines, abandoned spur roads, and roadsides can be seeded and fertilized.

Forage enhancement for deer and elk can potentially benefit conifer growth. Campbell and Evans (1978) and Smith (1980) reported that providing preferred forage on clearcuts may result in a reduction of browsing on conifers. Also, nitrogen-fixing species such as legumes seeded for wildlife use can increase the soil nutrient content for conifers (Haines and DeBell 1980).

Prescribed burning to dispose of slash or to maintain openings, improves the quality and quantity of forage for deer and elk (Taber 1973). Burning also creates a good seedbed for windblown and residual seed germination, and stimulates shrub sprouting while removing barriers which might impede animal access.

Increase Area in Forage Production

There are large acreages in western Oregon and Washington where thinning treatments would increase timber production (Gedney 1982, MacLean 1980). Thinning designed to reduce canopy closures to less than 60 percent would increase the quantity and quality of forage available to deer and elk if slash does not limit animal access. Thinned blocks, however, should be alternated with unthinned blocks to maintain areas of thermal cover. Seeding forage species and fertilization immediately following thinning will further improve forage.

Shortened timber harvest rotations will increase the area in forage production. A 40-year rotation on the same management unit should result in twice the forage-producing acreage as an 80-year rotation (Lawrence 1969). This approach for improving forage, however, must be weighed against its impact on the quantity and quality of cover which would be produced with such a short rotation.

Cover Improvement

Forest managers can provide thermal and optimal cover stands and improve their availability to deer and elk through the use of appropriate silvicultural practices and harvesting patterns. Cover stands will provide more suitable deer and elk habitat if they are dispersed spatially throughout the management unit, and are of adequate structure and acreage to meet the animals' cover needs. Energy expenditures of deer and elk will be reduced if summer and winter ranges, foraging areas, and special areas within those ranges are linked by corridors of forest cover (fig. 24). Forage areas will receive more deer and elk use if shielded from roads by screens of hiding cover or topographic features.

Important elements of optimal cover are cool temperatures that relieve animals from heat stress during hot summer weather, and snow interception capability, forage from the understory, and litterfall during severe winter weather. These elements occur in older stands through natural succession, however, it may be possible to develop optimal cover characteristics in younger stands through stocking control, forage seeding, fertilization, and thinning programs (see chapter 14).

Another approach for improving overall cover quality would be to manage a portion of the timber resource within the management unit on a long rotation, while the remainder was under a short

Figure 24.—Corridors of cover left for travel routes between important habitat areas will reduce energy expenditures for deer and elk.

Figure 25.—Important functions of optimal cover are the ability to intercept snow (above) and provide maintenance forage for animals during adverse winter weather (below).

rotation; that is, using two rotations (see chapter 14). The area under short rotation would provide forage areas, hiding, and thermal cover, while the area under the longer rotation would produce less forage, but would provide the optimal cover needed by the animals during adverse weather (fig. 25).

Roads and Public Access

Road construction and logging may temporarily displace deer and elk. By condensing activities in time and space, the manager can shorten the period of displacement.

Road closures to restrict public traffic in an area can reduce human disturbance to deer and elk. Closures also can improve the quality of the hunting experience (USDA Siuslaw National Forest 1976). Road closures become increasingly valuable in reducing human disturbance as more of a drainage basin is roaded. An analysis of areas to include in a road closure plan should consider 1) increasing foraging opportunities for deer and elk; 2) establishing priorities for closures based on areas of less than 50 percent slope, high site class, little forest cover, and near riparian habitat; 3) using the fewest road barriers to reduce traffic on the largest area; and 4) the ability to enforce the closure.

Habitat Planning and Evaluation

Management of habitat for deer and elk in western Oregon and Washington is largely dependent on the management of the timber resource. Each timber management decision may have an impact on deer and elk populations. These populations and their habitat requirements should be taken into consideration for both short and long-range planning for the management of forest land resources. With an interdisciplinary approach to the planning process, the opportunity exists to enhance the beneficial aspects and to ameliorate many of the detrimental aspects of timber management on deer and elk habitat.

A Suggested Approach

Earlier sections of this chapter have identified biological requirements of deer and elk and how these relate to silvicultural activities within the managed forest. The following section presents a seven-step approach the forest manager may use in setting and achieving deer and elk habitat objectives within the overall forest management plan.

Forest managers are encouraged to evaluate the influence of various land management practices on deer and elk habitat. They should address certain basic questions such as: Will a particular silvicultural prescription result in more or less productive habitat for deer and elk? How do alternative management plans rank in producing productive habitat for deer and elk? Additionally, limiting factors should be identified and methods proposed to decrease the effect of these factors and meet management objectives.

1. Setting Objectives

The first step in developing a meaningful program for the management of deer and elk habitat is to adopt overall management objectives. These should be integrated with the game management objectives of the state wildlife agency, based on input from the public. These general objectives would translate to deer and elk habitat that would produce more, less, or the same number of animals in the future and should cover a broad area such as a national forest, a ranger district or a major stream drainage. The objectives also must be developed in concert with objectives for the

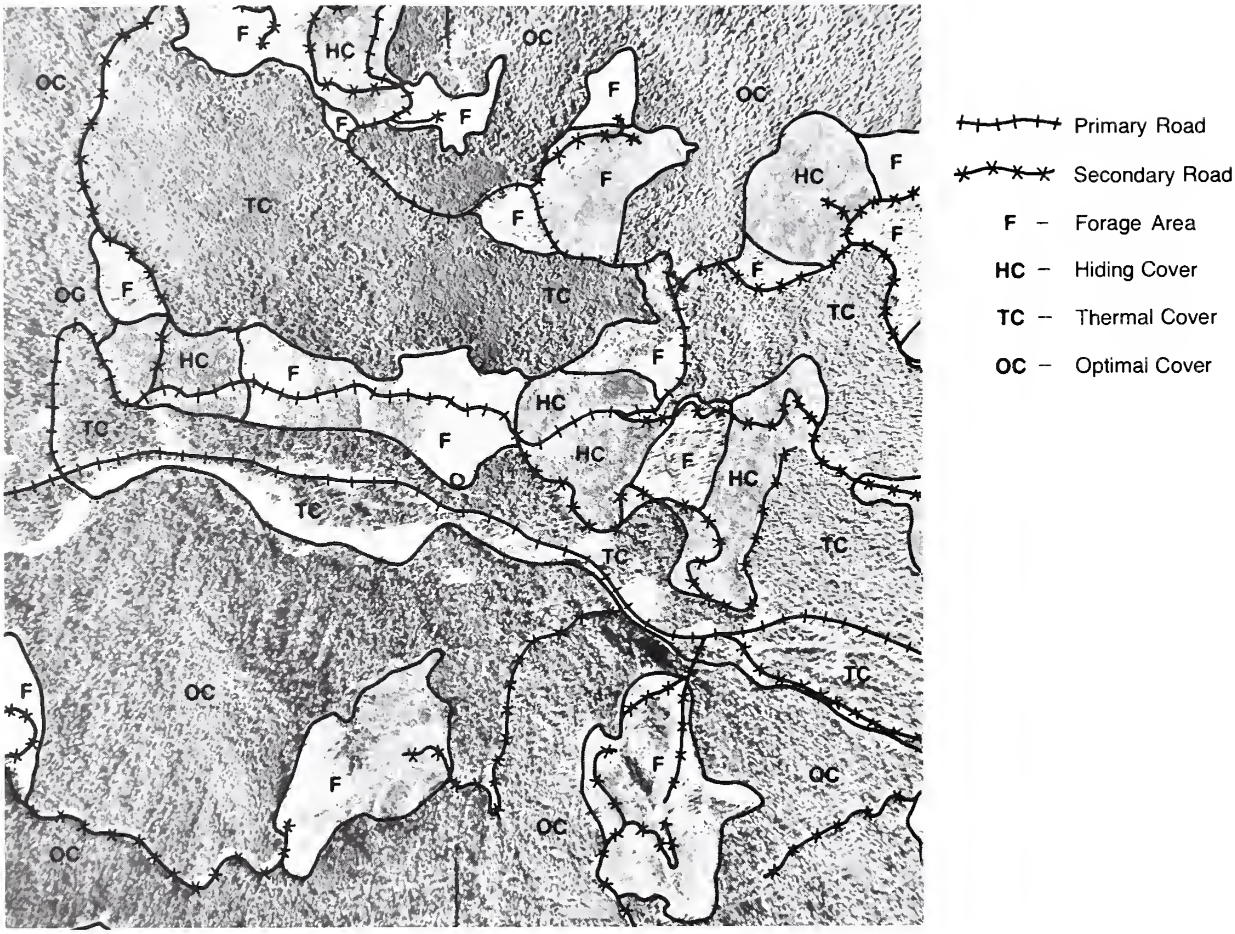


Figure 26.—Roads and major habitat components, including forage areas and hiding, thermal, and optimal cover areas, should be delineated on a base map.

management of other forest resources. This requires an interdisciplinary review to ensure that deer and elk are included in overall management objectives.

2. Select Management Units

After overall objectives for deer and elk management have been developed, the forest manager and wildlife biologist need to determine the size and location of individual management units and gather information concerning present habitat conditions in these units. The size of management unit recommended is a third- or fourth-order stream drainage, ranging from 1,000 to 6,000 acres. The management units should be delineated on aerial photos, forest type maps, or other resource mapping systems.

3. Identification of Habitat Components

On the base map delineate the boundaries and determine the acreage of all major habitat components — forage areas, hiding cover, thermal cover, and optimal cover (fig. 26). Forage areas, thermal cover, and optimal cover can readily be identified. Forage areas will generally be those in the grass-forb, shrub, and open sapling-pole stand conditions. Thermal cover areas will generally be those in the closed sapling-pole-sawtimber stand condition, while optimal cover will generally be those areas in the large sawtimber (21 inch d.b.h. or greater) and old-growth stand conditions.

Although all stand conditions from older forage areas through old-growth timber may provide hiding cover, the only areas that should be mapped as hiding cover are young sapling-pole stands that have not matured enough to be classified as thermal cover. Thinned stands not meeting the thermal cover definition simply because the canopy has been reduced to less than 70 percent should be mapped as "potential" thermal cover. Road systems also should be shown on the map.

4. Evaluate the Current Habitat Productivity for the Management Unit

A method for evaluating current habitat conditions and a basis for comparing these conditions with those resulting from proposed future management practices, is essential to the planning process. A number of agencies and researchers have proposed methods of evaluating habitat productivity or suitability. The U.S. Fish and Wildlife Service has developed a habitat evaluation procedure (HEP) that uses habitat suitability indices (HSI) (Schaumberger and

Farmer 1978). The USDA Forest Service has developed a survey and production rating system (USDA Forest Service 1971). An index of wildlife habitat quality was presented by Short (1982) in a habitat gradient model. Thomas et al. (1976) discussed the use of cover/forage ratios as an integrated habitat factor illustrating potential change of elk use in response to varying the relation of cover and forage areas. Giles (1978), Marcot and Meretsky (1983), Patton (1975), and Schuerholz (1974) have discussed the measurement of edge as an indicator of habitat distribution, while Heinen and Cross (1983) expanded this approach by including interspersion, juxtaposition and spatial diversity. Walters and Gross (1972), Bunnell (1974), and Mealey et al. (1982) presented more complex methods using computer simulation to interpret a set of variables and formulate management decisions. Although not all-inclusive, these methods illustrate the variety of techniques available and their respective degree of complexity. Each method is constrained by its own set of limitations and assumptions. The evaluation method used should be adapted to conditions in the local area and the data base available.

Figure 27.—Snow depths of 18 inches or more hinder animal movement and cover most forage in clearcut areas.

5. Setting Objectives for Deer and Elk Habitat Productivity for Management Units

With the data collected in steps 2 and 3 and the evaluation of current conditions developed in step 4, the land manager and wildlife biologist are in a position to develop specific objectives for individual units, the sum of which should fulfill the overall objective developed in step 1. Points to consider are: 1) Is the unit under consideration primarily summer range, winter range, or both: 2) Are winters of such severity that optimal cover should be available (fig. 27); 3) Does the degree of summer heat and solar radiation create a need for optimal cover to relieve the animals from heat stress while still providing some succulent forage? 4) Where optimal cover should be available, what size and distribution of cover blocks will best meet the needs of the animals; 5) What is the current productivity level of the unit and its potential for alteration or improvement? The unit objective should be compatible with the overall objective and the unit's potential.

6. Develop a Management Plan to Meet the Objectives Established for the Unit

The management plan must be coordinated with other resource objectives and will require close cooperation between all resource managers.

Timber harvest rotation lengths need to be determined that will produce and sustain the desired habitat conditions (i.e., forage-cover ratios) over time. Placement of timber harvest units and other silvicultural or enhancement practices are then planned, modified, or constrained in time and space to meet the objectives. Road management programs should be considered to help achieve deer and elk habitat management goals.

The final plan can be used to assess potential constraints on annual harvest volume, to develop rotation lengths, or to identify conflicts with other resource objectives (see chapters 14 and 15).

7. Establish a Monitoring Program

The final step in habitat management planning and evaluation is to establish a monitoring program. Procedures used and information collected should be coordinated with the state wildlife agency. Two primary questions should be addressed: 1) Are the silvicultural prescriptions identified in the plan being implemented, and 2) Are the deer and elk populations responding as expected? The final question is important because deer and elk population responses to habitat manipulation are not always predictable — responses vary from area to area depending on local conditions. This information will provide a basis for making future adjustments in the unit management program.

Management Considerations

The following management considerations and options are points that managers may want to consider if maintenance or improvement of deer and elk habitat is one of their management objectives. Where conflicts are apparent, consultation with wildlife biologists should help integrate management of the timber and wildlife resources.

Roads

Location and Design

Considerations

Maintain big game travel routes, protect key summering areas, critical winter ranges, and calving and fawning areas.

Options

- Locate roads to avoid special areas such as riparian zones, wetlands, or natural openings;
- Locate landings to give maximum yarder reach thus minimizing the road construction required;
- Utilize terrain features to screen road traffic from adjacent areas;
- If roadway banks prevent animals from crossing, develop access routes in steep cutbanks or fills.

Road Management

Consideration

Reduce human disturbance of deer and elk.

Options

- Provide vegetative strips along main haul roads to screen road traffic from adjacent areas;
- Harvest timber in narrow strips along roads and permit these buffers to grow up to provide visual barriers before harvesting timber behind the buffers;
- Develop only temporary access roads into the immediate area of a timber harvest operation and permanently close the road when the harvest is completed;
- Gate or otherwise close secondary roads when not in use;
- Restrict public use by closing secondary and primary roads where possible during critical periods such as hunting seasons, the winter months on winter range, or during calving and fawning periods (fig. 28).
- Regulate road and off-road use by snowmobiles, motorcycles, and other all-terrain vehicles; and

- Concentrate the above road management practices on areas with slopes of less than 50 percent, fertile soils, little cover, riparian zones, and forage improvement sites.

Silviculture

Scheduling of Harvest Units

Consideration

Maximize beneficial effects of timber harvesting, improve habitat diversity, maintain a balance of forage and cover on both summer and winter ranges over time through incremental cutting, maximize habitat edge.

Options

- Spread harvesting within a management unit over the entire rotation period;
- Disperse harvest units within a management unit at low-, mid- and high-elevation during the same time frame in order to achieve a year-round balance of forage and cover;
- Distribute harvest units over the entire management unit to avoid the cumulative effect of adjacent clearcuts becoming one large clearcut in forage condition;
- A proposed harvest unit should have no more than one-quarter of its border adjacent to hiding cover;
- A proposed harvest unit should have at least one-half of its border adjacent to thermal cover stands of 30 acres or more;
- A proposed harvest unit on a winter range where snow depths become critical should have at least one-half of its border adjacent to optimal cover stands of 30 acres or more;
- Schedule harvest operations for areas that will create the least disturbance for deer or elk during their critical periods (wintering, breeding, calving/fawning);
- Locate harvest units to create forage areas within large uncut blocks; and
- Use computer models as an aid in planning harvest programs to optimize forage and cover conditions over time and space.

Design and Layout of Harvest Units

Consideration

Manage for effective use of forage and cover blocks, maintain riparian vegetation.

Options

- Design harvest units to conform to topographic features of the landscape;
- Harvest in units so that all portions of the unit are within 600 feet of cover;
- Manage riparian zone vegetation along third-order and larger streams to provide hiding cover and travel corridors;
- Wait until clearcuts have reached the closed sapling-pole stand condition before harvesting adjacent cover areas;
- Leave patches of residual vegetation for hiding cover in large clearcuts (when the edge is more than 600 feet from the center);
- Leave buffer strips to screen natural openings such as wet meadows; and
- Leave travel corridors of hiding cover between natural openings and nearby cover blocks.

Figure 28.—Deer and elk need areas with a balance of forage and cover that are protected from disturbance for fawning and calving.

Debris Management

Consideration

Maintain access for foraging, make use of debris for cover, eliminate barriers to travel.

Options

- Broadcast burn slash and small debris while ground is damp to protect root systems of forage species;
- If the area is scarified, provide openings in debris windrows every two or three hundred feet to allow passage routes for deer and elk; and
- Windrow debris parallel to roads to serve as visual barriers and protective cover for deer and elk.

Herbicide Applications

Consideration

Protect riparian and travel corridor vegetation, protect visual barriers along roads, protect important deer and elk forage species.

Options

- Use herbicides having the least impact on desirable forage species consistent with forestry objectives;
- Time applications to have the least impact on desirable forage species; and
- Avoid application of herbicides within riparian zones, travel corridors, or roadside screening vegetation.

Precommercial Thinning

Consideration

Improve forage, maintain access for deer and elk, maintain a forage component that will remain as the stand develops, accelerate the successional pattern toward optimal cover.

Options

- Thin before canopy closure eliminates the forage species on the forest floor;
- Thin to 60 percent crown cover or less to improve the quantity and quality of deer and elk forage species;
- Thin when trees are 10-13 feet in height to reduce barriers created by slash accumulations;
- When thinning older stands, lop and scatter or gather and stack trees removed in the thinning process to provide access for deer and elk;
- Clear travel lanes for deer and elk through thinned areas if no other slash disposal is planned; and
- On winter range, thin to the number of trees per acre that will meet the objective of providing trees with snow intercept capabilities at the earliest possible time.

Commercial Thinning

Consideration

Improve forage for deer and elk, provide adequate thermal cover where needed, accelerate the successional pattern toward optimal cover.

Options

- Thin to 60 percent crown cover or less if an objective is to provide forage for deer and elk;
- Maintain 70 percent or greater crown cover if an objective is to maintain thermal cover and snow intercept;
- Alternate blocks thinned to less than 60 percent crown cover with blocks having greater than 70 percent crown cover; and
- If an objective is to obtain optimal cover at the earliest possible date, thin to the degree that will permit the most rapid growth and structural development of the desired number of overstory trees.

Habitat Improvement Procedures

Seeding, Planting, and Fertilization

Consideration

Improve forage quantity and quality for deer and elk.

Options

- After clearcutting or final removal of shelterwood trees, seed forage that is palatable and nutritious for deer and elk;

Figure 29.—Forage seeding and fertilization can improve the quantity and quality of forage for deer and elk.

- Fertilize seeded or planted forage twice, first for establishment and later to stimulate growth and increase the nutritive value (fig. 29); and
- Establish tree stocking rates that will allow the longest period before canopies close and shade out understory forage species, while still achieving objectives for final stocking levels of merchantable trees.

Forage Area Maintenance

Consideration

Provide permanent forage on certain critical areas where land use constraints preclude timber production or where deer and elk values are the primary consideration.

Options

- Maintain the area permanently in an early successional vegetative stage; and
- Plant and fertilize preferred deer and elk forage.

Management of Optimal Cover

Consideration

On critical deer and elk ranges, maintain selected areas of forest tree cover that meet the definition of optimal cover.

Options

- Maintain the amount of optimal cover on the winter range required to meet the needs of deer and elk during weather of a severity common for that region;
- In areas having consistently high summer temperatures maintain a portion of the range in optimal cover to provide an area where the animals can get maximum relief from heat stress and obtain some succulent forage;
- Forego the option for harvesting timber in certain areas to be left in large saw-timber or old-growth stand conditions providing optimal cover for deer and elk;
- Manage portions of the winter range on a long rotation to insure that some areas are always in the large saw-timber or old-growth stand conditions; and
- Intensively manage younger stands to produce optimal cover characteristics in less time than it will take them to develop in an unmanaged stand.

References Cited

Agpaoa, E. The effect of nitrogen fertilization on the diet quality and selenium concentrations in black-tailed deer (Odocoileus hemionus) forage. Arcadia, CA: Humboldt State University; 1981. 23 p.

Baile, C. A.; Forbes, J.M. Control of feed intake and regulation of energy balance in ruminants. Physiol. Rev. 54(1): 160-214; 1974.

Bailey, V. The mammals and life zones of Oregon. North American Fauna No. 55. Washington, DC: U.S. Department of Agriculture, Bureau of Biological Survey; 1936. 416 p.

Bard, R. Landforms. In: Highsmith, R. M., Jr. ed. Atlas of the Pacific Northwest. 5th ed. Corvallis, OR: Oregon State University Press; 1973: 34-42.

Black, H. C.; Dimock II, E. J.; Evans, J.; Rochelle, J. A. Animal damage to coniferous plantations in Oregon and Washington: Part I, a survey, 1963-1973. Corvallis, OR: Oregon State University, School of Forestry; Res. Bull. 25; 1979.

Blaxter, K. L. The energy metabolism of ruminants. London: Hutchinson, Scientific and Technical; 1962. 329 p.

Bramble, W. C.; Byrnes, W. R. A long term ecological study of game food and cover on a sprayed utility right-of-way. Lafayette, IN: Purdue University, Agricultural Experiment Station; Res. Bull. 885; 1972. 20 p.

Brown, E. R. The black-tailed deer of western Washington. Biological Bull. 13. Olympia, WA: Washington Department of Game; 1961. 124 p.

Brown, E. R.; Mandery, J. H. Planting and fertilization as a possible means of controlling distribution of big game animals. J. For. 60: 33-35; 1962.

Bunnell, F. L. Computer simulation of forest-wildlife relations. In: Black H. C. ed. Wildlife and forest management in the Pacific Northwest. Corvallis, OR. Corvallis, OR; Oregon State University, School of Forestry. 1974: 39-50.

Bunnell, F. L.; Eastman, D. S. Effects of forest management practices on wildlife in the forests of British Columbia. In: Proceedings, Division I. XVI IUFRO World Congress. Oslo, Norway: 1976: 631-689.

Campbell, D. L.; Evans, J. Establishing selected native forbs to provide compatible deer use of Douglas-fir plantations. Olympia, WA: U.S. Department of the Interior, Fish and Wildlife Service; 1978.

Campbell, D. L.; Johnson, L. E. Guide for collecting and seeding native forbs for wildlife in Douglas-fir clearcuts. Wildlife Leaflet 513. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service; 1981. 13 p.

Cleary, B. Wildlife seeding guide for western Oregon. Portland, OR: Oregon Department of Fish and Wildlife; 1972.

Crouch, G. L. Forage production and utilization in relation to deer browsing of Douglas-fir seedlings in the Tillamook Burn, Oregon. Corvallis, OR: Oregon State University; 1964. 162 p. Dissertation.

Crouch, G. L. Forage availability in relation to browsing of Douglas-fir seedlings by black-tailed deer. J. Wildl. Manage. 32: 542-553; 1968.

Edgerton, P. J.; McConnell, B. R. Diurnal temperature regimes of logged and unlogged mixed conifer stands on elk sumer range. Res. Note PNW-277. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1976.

Franklin, J. F. Personnel communication. U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station, Forestry Sciences Laboratory; Corvallis, OR. 1983.

Franklin, J. F.; Cromack, K. Jr.; Denison, W. [and others]. Ecological characteristics of old-growth Douglas-fir forests. Gen. Tech. Rep. PNW-118. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 48 p.

Geiger, R. The climate near the ground. 4th ed. Cambridge, MA: Harvard University Press; 1965. 611 p.

Gedney, D. R. The timber resources of western Oregon – highlights and statistics. Resour. Bull. PNW-97. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1982. 84 p.

Geist, V. Behavior. In: Schmidt, J.; Gilbert D. comps., eds. Big game of North America: ecology and management. Harrisburg, PA: Stackpole Books; 1978: 283-296.

Giles, R. H. Habitat analysis and design. In: Wildlife Management. San Francisco, CA: W. H. Freeman and Company; 1978: 119-209.

Gratkowski, H. Silvicultural use of herbicides in Pacific Northwest forest. Gen. Tech. Rep. PNW-37. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1975. 44 p.

Haines, S. G.; DeBell, D. S. Use of nitrogen-fixing plants to improve and maintain productivity of forest soils. In: Impact of intensive harvesting on forest nutrient cycling: Proceedings of a symposium; 1979 August 13-16; Syracuse, NY: State University of New York, College of Environmental Science and Forestry; 1980: 279-303.

Hanley, T. A. Black-tailed deer, elk, and forest edge in a western Cascades watershed. J. Wildl. Manage. 47: 237-242; 1983.

Hanley, T. A. Cervid activity patterns in relation to foraging constraints: western Washington. Northwest Sci. 56(3): 208-217; 1982.

Hanson, W. O.; Smith, J. G. Significance of forage quality as a tool in wildlife management. In: Range and wildlife habitat evaluation – a research symposium. Flagstaff, AZ: U.S. Department of Agriculture, Misc. Publ. No. 1147; 1970. 25-31.

Happe, P. J. Use of suburban habitats by Columbian black-tailed deer. Corvallis, OR: Oregon State University; 1983. 105 p. Thesis.

Harestad, A. S.; Bunnell, F. L. Snow and its relationship to deer and elk in coastal forests. Vancouver, B. C.: University of British Columbia. 1979. 53 p.

Harper, J. A. Ecology of Roosevelt elk. P-R Proj. W-59-R. Portland, OR: Oregon State Game Commission; 1971. 44 p.

Harper, J. A.; Swanson, D. O. The use of logged timberland by Roosevelt elk in southwest Oregon. Boise, ID: 50th Proceedings Western Association State Game and Fish Commissioners; 1970: 318-341.

Harper, J. A.; Trainer, C. E. Ecological study of Roosevelt elk. Job Progress Rep., July 1, 1968-June 30, 1969. P-R Proj. W-59-R-6. Portland, OR: Oregon State Game Commission; 1969. 12 p.

Heinen, J.; Cross, G. H. An approach to measure interspersion, juxtaposition, and spatial diversity from cover-type maps. Wildl. Soc. Bull. 11: 232-237; 1983.

Hines, W. W. Black-tailed deer populations and Douglas-fir reforestation in the Tillamook Burn, Oregon. Game Res. Rep. 3; Corvallis, OR: Oregon Department of Fish and Wildlife, Research Division. 1973. 59 p.

Hines, W. W. Black-tailed deer behavior and population dynamics in the Tillamook Burn, Oregon. Wildl. Res. Rep. 5. Corvallis, OR: Oregon State University; Oregon Department of Fish and Wildlife, Research Division; 1975. 31 p.

Hungerford, K. E. Influence of forest management on wildlife. In: Black, H. C., ed. Wildlife and reforestation in the Pacific Northwest, Proceedings. Corvallis, OR: Oregon State University, School of Forestry; 1969. 92 p.: 39-41.

Hynson, J.; Adamus, P.; Tibbetts, S.; Darnell, R. Handbook for protection of fish and wildlife from construction of farm and forest roads. OBS-82/18. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service; 1982. 153 p.

Jameson, D. A. Relationship of tree overstory and herbaceous understory vegetation. J. Range Manage. 20(4): 247-249; 1967.

Janz, D. W. Preliminary observations on seasonal movements and habitat use by Vancouver Island Roosevelt elk. In: MacGregor, W., ed. Proceedings of the western states elk workshop. Cranbrook, BC. Victoria, BC: British Columbia Fish and Wildlife Branch; 1980: 115-142.

Jenkins, K. J. Home range and habitat use by Roosevelt elk in the Olympic National Park, Washington. Corvallis, OR: Oregon State University; 1979. 94 p. Thesis.

Jenkins, K.; Starkey E. Roosevelt elk of the Hoh Valley, Olympic National Park. Corvallis, OR: National Park Service, Oregon State University, School of Forestry, Oregon Cooperative Park Studies Unit; 1980; Report 80-3. 32 p.

Jenkins, K. J.; Starkey, E. E. Social organization of Roosevelt elk in an old-growth forest. J. Mamm. 63:331-334; 1982.

Jones, G. Influence of forest development on black-tailed deer winter range on Vancouver Island. In: Black, H. C., ed. Wildlife and forest management. Corvallis, OR. Corvallis, OR: Oregon State University, School of Forestry; 1974: 139-148.

Jones and Stokes Associates, Inc. Wildlife community composition of unmanaged young growth Douglas-fir forests. Sacramento, CA: Jones and Stokes Associates, Inc. 2321 P Street; 1980. May; 72 p.

Juday, G. P. Location, composition and structure of old-growth forests of the Oregon Coast Range. Corvallis, OR: Oregon State University; 1977. 218 p. Dissertation.

Krueger, W. C. How a forest affects a forage crop. Rangelands. 3:70-71; 1981.

Lawrence, W. The impact of intensive forest management on wildlife populations. In: Black, H. C., ed. Wildlife and reforestation in the Pacific Northwest, Proceedings. Corvallis, OR: Oregon State University, School of Forestry; 1969: 72-74.

Leckenby, D. A. Management of mule deer and their habitat: applying concepts of behavior, physiology and microclimate. Boise, ID: 57th Proceedings Western Association of State Game and Fish Commissioners; 1977: 206-217.

Lee, R. Forest microclimatology. New York: Columbia University Press; 1978. 276 p.

Leege, T. A. Relationship of logging to decline of the Peter King elk herd. In: Heib, S. R. ed. Proceedings of the elk-logging-roads symposium. 1975 December 16-17; Moscow, ID. Moscow, ID: University of Idaho; 1976: 6-10.

Lemos, J. C.; Hines, W. W. Guidelines for enhancing big game values on forestlands. Job progress rep. W-70-R-4, G-I-5. Portland, OR: Oregon Department of Fish and Wildlife; 1974. 36 p.

Leslie, D. M. Jr. Nutritional ecology of cervids in old-growth forests in Olympic National Park, Washington. Corvallis, OR: Oregon State University; 1983. 154 p. Dissertation.

Long, J. N. Forest vegetation dynamics within the *Abies amabilis* zone of a western Cascades watershed. Seattle, WA: University of Washington; 1976. 175 p. Dissertation.

Luman, I. D.; Neitro, W. A. Preservation of mature forest seral stages to provide wildlife habitat diversity. 45th North Am. Wildl. and Nat. Resour. Conf. Trans. Washington, DC: Wildlife Management Institute; 1980: 217-277.

Lyon, L. J. Habitat effectiveness for elk as influenced by roads and cover. J. For. 77: 658-660; 1979.

Lyon, L. J.; Basile, J. V. Influences of timber harvesting and residue management on big game. Gen. Tech. Rep. INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980: 441-453.

MacLean, C. D. Opportunities for silvicultural treatment in western Oregon. Resource. Bull. PNW-90. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 35 p.

Marcot, B. G.; Meretsky, V. J. Shaping stands to enhance habitat diversity. J. For. 81(8): 526-528; 1983.

Mealey, S.P.; Lipscomb, J. F.; Johnson, K. N. Solving the habitat dispersion problem in forest planning. 47th North Am. Wildl. and Nat. Resour. Conf. Trans. Washington, DC: Wildlife Mangement Institute; 1982: 142-153.

Mereszczak, I. M.; Krueger, W. C.; Vavra, M. Effects of range improvement on Roosevelt elk winter nutrition. J. Range Manage. 34: 184-187; 1981.

Merrill, E. H.; Taber, R. D.; Raedeke, K. J. Elk populations in the northwest section of the Mount St. Helen's blast zone. Centralia, WA: The Weyerhaeuser Corporation, Western Forestry Research Center; 1983; Prog. Rep. (Mimeo.) 49 p. + figures and appendices.

Meslow, E. C.; Maser, C.; Verner, J. Old-growth forests as wildlife habitat. 46th North Am. Wildl. and Nat. Resour. Conf. Trans. Washington, DC: Wildlife Management Institute; 1981: 329-335.

Miller, F. L. Observed use of forage and plant communities by black-tailed deer. J. Wildl. Manage. 32: 142-148; 1968.

Miller, F. L. Distribution patterns of black-tailed deer in relation to environment. J. Mamm. 51: 248-260; 1970.

Moen, A. N. Wildlife ecology: an analytical approach. San Francisco, CA: W. H. Freeman and Co.; 1973. 458 p.

Moen, A. N.; Stevens, D. Functional aspects of wind as an ecological and thermal force. 35th North Am. Wildl. and Nat. Resour. Conf. Trans. Washington, DC: Wildlife Management Institute; 1970: 106-114.

Mount, L. E. The concept of thermal neutrality. In: Monteith, J. L.; Mount, L. E., eds. Heat loss from animals and man. London: Butterworths; 1974: 425-439.

Newman, C. C. Elk annual report. N2619. Port Angeles, WA: U.S. Department of the Interior, National Park Service, Olympic National Park. 1956. 12 p.

Patton, D. R. A diversity index for quantifying habitat "edge". Wildl. Soc. Bull. 3(4): 171-173; 1975.

Pedersen, R. J.; Adams, A. W.; Skovlin, J. M. Elk habitat use in an unlogged and logged forest environment. Wildl. Res. Rep. 9. Portland, OR: Oregon Department of Fish and Wildlife, Research and Development Section; 1980. 121 p.

Peek, J. M.; Scott, M. D.; Nelson, L. J. [and others]. Role of cover in habitat management for big game in northwestern United States. 47th. North Am. Wild. and Nat. Resour. Conf. Trans. Washington, D. C.: Wildlife Mangement Institute; 1982: 363-373.

Robbins, C. T. Wildlife feeding and nutrition. New York; Academic Press; 1983. 343 p.

Roberts, H. B. Effects of logging on elk calving habitat, Mover Creek. Salmon, ID: U.S. Department of Agriculture, Forest Service, Salmon National Forest; 1974. 22 p.

Rochelle, J. A. Effects of forest fertilization on wildlife. In: Gessel, S. P.; Kenady, R. M.; Atkinson, W. A., eds. Proceedings – forest fertilization conference. Seattle, WA. Inst. For. Resour. Contrib. 40 Seattle, WA: University of Washington, College of Forest Resources; 1979: 163-168.

Rochelle, J. A. Mature forests, litterfall and patterns of forage quality as factors in the nutrition of black-tailed deer on northern Vancouver Island. Vancouver, BC: University of British Columbia; 1980. 296 p. Dissertation.

Rochelle, J. A.; Bunnell, F. L. Plantation management and vertebrate wildlife. In: Ford, E. D., ed. The ecology of even-aged plantations. Cambridge, U.K. Institute of Terrestrial Ecology; 1979: 389-411.

Schamberger, M.; Farmer, A. The habitat evaluation procedures: their application in project planning and impact evaluation. 43rd North Am. Wildl. and Nat. Resourc. Conf. Trans.; Washington, DC: Wildlife Management Institute; 1978: 274-283.

Schoen, J. W. The ecological distribution and biology of wapiti in the Cedar River Watershed, Washington. Seattle, WA: University of Washington. 1977. 408 p. Dissertation.

Schuerholz, G. Quantitative evaluation of edge from aerial photographs. J. Wildl. Manage. 38: 913-920; 1974.

Schwartz, J. E. The Olympic elk study. Olympia, WA: U.S. Department of Agriculture, Forest Service, Olympic National Forest; 1939. 123 p. + maps.

Short, H. L. Development and use of a habitat gradient model to evaluate wildlife habitat. 47th. North Am. Wildl. and Nat. Resour. Conf. Trans. Washington, DC: Wildlife Management Institute; 1982: 57-73.

Smith, S. P. Forage seeding for elk management. Corvallis, OR: U.S. Department of Agriculture, Forest Service, Suislaw National Forest; 1980. 3 p.

Staneck, W.; Beddows, D.; State, D. Fertilization and thinning effects on a Douglas-fir ecosystem at Shawingan Lake on Vancouver Island. Rep. BC-R-1. Victoria, BC: Environment Canada, Pacific Forest Research Centre; 1979. 11 p.

Starkey, E. E.; deCalesta, D. S.; Witmer, G. W. Management of Roosevelt elk habitat and harvest. 47th North Am. Wildl. and Nat. Resour. Conf. Trans. Washington, DC: Wildlife Management Institute; 1982: 353-362.

State of Oregon. The Oregon interagency guide for conservation and forage plantings. Portland, OR: Joint publication of the State of Oregon(Oregon State University and Oregon Department of Fish and Game), U.S. Department of Agriculture (Forest Service and Soil Conservation Service), and U.S. Department of the Interior (Bonneville Power Administration and Bureau of Land Management); 1980. 84 p.

State of Washington. The Washington interagency guide for conservation and forage plantings. Washington State Rangeland Committee. Misc. Pub. 0058. Pullman, WA: Washington State University, Cooperative Extension; 1983. 70 p.

Swanson, D. O. Roosevelt elk-forest relationships in the Douglas-fir region of the southern Oregon Coast Range. Ann Arbor, MI: University of Michigan; 1970. 186 p. Dissertation.

Taber, R. D. Effects of even-age forest management on big game. In: Hermann, R. K.; Lavender, D. P., eds. Even-age management symposium. Corvallis, OR. Corvallis, OR: Oregon State University, School of Forestry; 1973: 59-74.

Taber, R. D.; Hanley, T. A. Black-tailed deer and forest succession in the Pacific Northwest. In: Wallmo, O. C.; Schoen, J. W., eds. Sitka black-tailed deer conference. Juneau, AK. Juneau, AK: U.S. Department of Agriculture, Alaska Region; 1979: 33-52.

Taber, R. D.; Raedeke, K. J. Roosevelt elk of the Olympic National Forest. Status Rept. Olympia, WA: U.S. Department of Agriculture, Forest Service, Olympic National Forest. 1980a. 107 p.

Taber, R. D.; Raedeke, K. J. Black-tailed deer of the Olympic National Forest. Status Rept. Olympia, WA: U.S. Department of Agriculture, Forest Service, Olympic National Forest. 1980b. 90 p.

Taber, R. D.; Manual, D.; West, S. D. [and others]. Wildlife management in the mesic-temperate forest of Washington and Oregon. In: Proceedings, Division I, XVII IUFRO World Congress. 1981: 575-589.

Taber, R. D.; Scott, D. R. M.; Driver, C. [and others]. Wildlife response to rights-of-way management. Rept. Research Proj. 63-1013; Seattle, WA: University of Washington, College of Forest Resources; 1972. 8 p. (mimeog.)

Taylor, R. H.; Johnson, R. L. Big game habitat improvement project in Western Washington 1967-1976. P-R Proj. W-74-R. Final Rep. Olympia, WA: Washington Department of Game; 1976. 220 p.

Thomas, J. W.; Toweill, D. E., comps., eds. Elk of North America: ecology and management. Harrisburg, PA: Stackpole Books; 1982. 698 p.

Thomas, J. W.; Black, H. Jr.; Scherzinger, R. J.; Pedersen, R. J. Deer and elk. Chapter 8. In: Thomas, J. W., ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture; 1979: 104-127.

Thomas, J. W.; Miller, R. J.; Black, H. [and others]. Guidelines for maintaining and enhancing wildlife habitat in forest management in the Blue Mountains of Oregon and Washington. 41st North Am. Wildl. and Nat. Resour. Conf. Trans. Washington, DC: Wildlife Mangement Institute; 1976: 452-477.

U.S. Department of Agriculture, Forest Service. Wildlife surveys handbook: FSH 2609.21 R6. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1971. 25.32 — p. 7-9 and 11-17.

U.S. Department of Agriculture, Forest Service, Siuslaw National Forest. Road closure report. Corvallis, OR: U.S. Department of Agriculture, Forest Service, Siuslaw National Forest; 1976. 13 p.

Wallmo, O. C., comp.ed. Mule and black-tailed deer of North America. Lincoln, NE: University of Nebraska Press; 1981. 605 p.

Walters, C. J.; Gross, J. E. Development of big game management plans through simulation modeling. J. Wildl. Manage. 36: 119-128; 1972.

Washington Game Department. Life history information for the black-tailed deer in Washington. Olympia, WA: Washington Department of Game; 1974. 14 p.

West, S. D.; Taber, R. D.; Anderson, D. A. Wildlife in sludge-treated plantations. In: Bledsoe, C. S., ed. Municipal sludge application to Pacific Northwest forestlands. Proc. Symposium. 1981; Seattle, WA. Inst. For. Resourc. Contrib. 41 Seattle, WA: University of Washington, College of Forest Resources; 1981. 155 p.

Willms, W. D. The influence of forest edge, elevation, aspect, site index, and roads on deer use of logged and mature forest, northern Vancouver Island. Vancouver, BC: University of British Columbia; 1971. 184 p. Thesis.

Witler, J. W. Effect of thinning intensity upon understory growth and species composition in an Oregon Coast Range *Pseudotsuga menziesii* stand. Corvallis, OR: Oregon State University; 1975. 87 p. Thesis.

Witmer, G. W. Roosevelt elk habitat use in the Oregon Coast Range. Corvallis, OR: Oregon State University; 1981. 104 p. Dissertation.

Yoakum, J.; Dasmann, W. P.; Sanderson, H. R. [and others]. Habitat improvement techniques. In: Schemnitz, S. D., ed. Wildlife management techniques manual, 4th ed. Washington, DC: The Wildlife Society; 1980: 329-403.

Zahn, H. Elk use of thermal cover on summer range in western Washington. Seattle, WA: University of Washington. Dissertation (in prep.).

Zahn, H. Personal communication. Wild. Bio., Washington Department of Game, Aberdeen, WA. Information presented to: Chapter 11 committee meeting; Portland, OR: Aug. 20, 1981.

Zasoski, R. J. Heavy metal mobility in sludge-amended soils. In: Bledsoe, C. S., ed. Municipal sludge application to Pacific Northwest forestlands. Proc. Symposium. 1981. Seattle, WA. Inst. For. Resour. Contrib. 41 Seattle, WA: University of Washington, College of Forest Resources; 1981. 155 p.

12

Northern Spotted Owls

Eric D. Forsman
Kirk M. Horn
Gerald W. Mires

Table of Contents

Introduction

Wildlife biologists and forest managers often use the presence or absence of one or more "indicator species" to predict whether an area of habitat is suitable for a variety of species having similar habitat requirements. In selecting an indicator species, biologists usually try to choose animals that require the largest areas of habitat. Managing habitat to support the species with the largest area requirements should provide for species that require smaller amounts of the same habitat or certain elements of that habitat. One species frequently used as an "indicator" in the Pacific Northwest is the spotted owl.

In the mountainous regions of the west are found three subspecies of the spotted owl: the northern, California, and Mexican (fig. 1). The northern spotted owl is found from the Cascade Range west to the coast in northern California, western Oregon and Washington, and southwestern British Columbia.

The northern spotted owl is closely associated with old-growth stand conditions in the temperate and high temperate conifer forest plant communities (Forsman 1976, U.S. Department of the Interior, Fish and Wildlife Service 1982). Recent studies indicate that northern spotted owl populations in Washington, Oregon and northern California are declining, concurrent with the gradual elimination of old-growth coniferous forests (Forsman 1976; Forsman et al. 1977; Garcia 1979; Gould 1974, 1977, 1979; Postovit 1979). As a result, management of the spotted owl has become a major concern to conservation and environmental groups as well as to wildlife biologists and forest managers. This chapter summarizes the available information on the biology and habitat needs of the spotted owl and describes a forest management program to provide habitat for the species. Although the discussion concentrates on Oregon and Washington, most of the information may be applied to northern California and British Columbia as well.

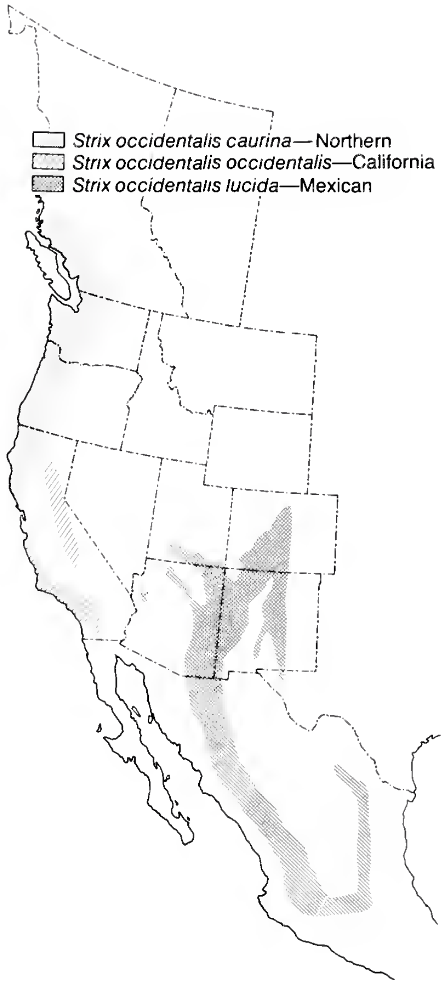


Figure 1.—Three subspecies of the spotted owl occur in mountainous areas in western North America.

Location and Identification of Spotted Owls and Their Nest Sites

Because spotted owls are inhabitants of dense forests, often in rugged terrain, historically they were seldom observed and were considered to be uncommon or rare throughout their range. Only in recent years have techniques been developed that have permitted the collection of reliable population data (Forsman 1976, Gould 1974 and 1977, Marcot and Gardetto 1980).

The most effective method for locating spotted owls is to imitate their calls at night; if present, the owls will usually call back at the suspected intruder. Tape-recorded calls played on portable recorders or vocal imitations of their calls are used to solicit a response from the owls. Either vehicle or hiking routes are laid out through forested areas with calling stops at 0.25- to 0.5-mile intervals (Forsman 1976). Most inventories are conducted between March and September when the owls are most vocal and the weather is most cooperative.

Locating actual nest sites is more difficult and may require a variety of techniques. If a pair of owls is consistently found in the same area during spring or summer, the nest tree is usually somewhere in the vicinity (fig. 2). During the breeding season, the birds often respond to calls in daylight hours and a careful observer may locate the birds roosting near the nest tree or going into or out of the nest cavity (Forsman 1976). After nesting has begun, the nest may be located by tethering a mouse near a roosting male and then observing the bird's flightpath after he captures the mouse and carries it to the nest.

Figure 2.—Spotted owls frequently roost near their nest sites, even in years when they are not nesting.

Anyone attempting to inventory spotted owls should be familiar with the calls and identifying characteristics of the barred owl. This larger relative is rapidly invading the range of the spotted owl in Washington, Oregon, and California (Reichard 1974, Taylor and Forsman 1976) and can be confused with the spotted owl.

Population Size and Spacing of Resident Pairs

Between 1969 and 1979, about one half of the potential habitat for spotted owls in Oregon was inventoried and over 600 pairs were located, suggesting a total population of about 1,200 pairs (Forsman et al. 1984). The proportion of total habitat that has been searched for spotted owls in Washington and California is unknown, but between 1973 and 1979, over 400 pairs of spotted owls were located in California (Gould 1974, 1977, 1979) and over 100 pairs in Washington (USDA Forest Service, Pacific Northwest Region, unpublished data).

All studies in Oregon, Washington, and northern California indicate a strong association between spotted owls and old-growth (over 200 years old) forests. In Oregon, 97 percent of all pairs located have been in old-growth forests and none have been located in forests younger than 36 years (Forsman et al. 1977, Forsman et al. 1984). In areas where old-growth and mature forests are both contiguous and extensive in Oregon, nest sites of spotted owl pairs are generally spaced one to two miles apart (Forsman 1980, Marshall 1942). Where areas of old-growth are more widely spaced, pairs are also more widely spaced. In areas where old-growth forests have been extensively logged and there are few if any timber stands over 80 years old, it is difficult to locate any evidence of a breeding population (Forsman et al. 1977, Postovit 1979).

Most spotted owls are found on federal lands. Of all known pairs in Oregon, 53 percent occupy lands administered by the USDA Forest Service and 40 percent occupy lands administered by the U.S. Department of the Interior, Bureau of Land Management. The occurrence on private and state lands is low, because most of these lands have been cut over within the last 70 years (Forsman 1976, Postovit 1979). These lands are now covered by second-growth forests that are too young to provide suitable habitat for spotted owls (fig. 3).

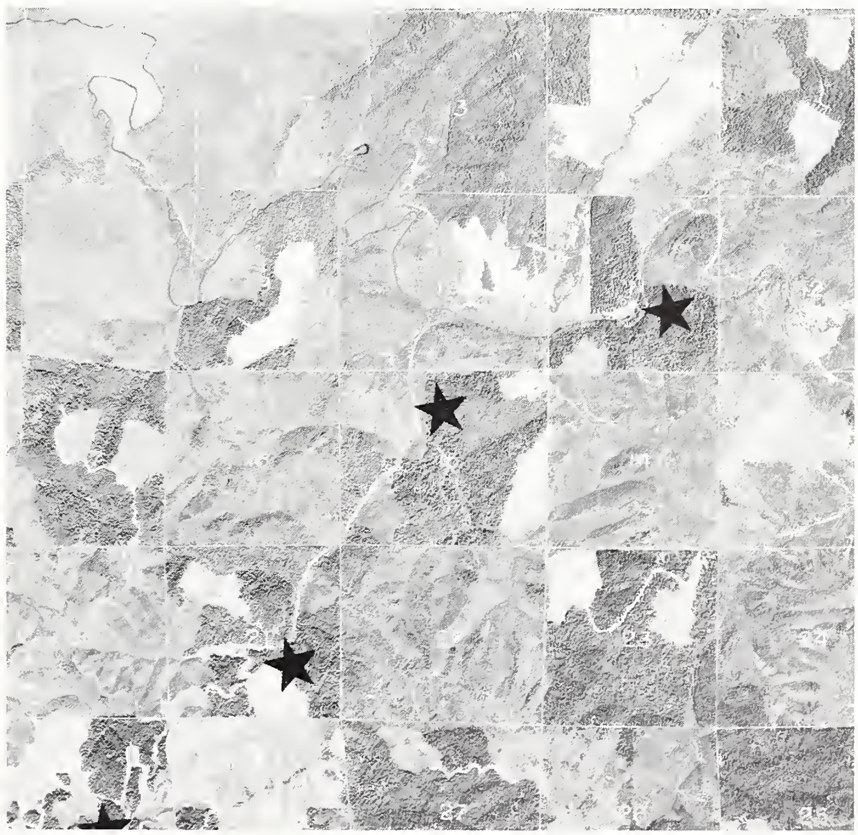


Figure 3.—In heavily cutover areas spotted owls are restricted primarily to the remaining stands of mature and old-growth forest. Stars indicate the location of nests and principal roost areas utilized by three pair of spotted owls.

Structural Characteristics of Optimal Habitat

The most consistent feature of old-growth forests occupied by spotted owls is an uneven-aged multilayered canopy (fig. 4) (Forsman 1976). Overstory trees are typically 230 to 600 years old. Understory trees are typically uneven in size and age, ranging from young saplings to large sawtimber (Franklin et al. 1981). Understory trees are generally shade-tolerant species, such as western hemlock, western redcedar, grand fir, white fir, Pacific yew, Shasta red fir, vine maple, canyon live oak, or tanoak. Although density and closure of individual canopy layers in these forests vary considerably, composite canopy closure is generally high (70-80 percent) as a result of the layered structure (fig. 4). Old-growth forests occupied by spotted owls are typically characterized by moderate to high numbers of old trees with structural damage and decay. Such trees are important as nest sites for the owls.

Figure 4.—Spotted owls prefer old-growth forests with multi-layered canopies. The nest of a spotted owl was located in this mixed stand of white fir, ponderosa pine, Shasta red fir and Douglas-fir in the southern Oregon Cascades.

Reproduction

Spotted owl pairs occupy the same territories year after year as long as suitable habitat is present (Bent 1938, Forsman 1976). Nest trees are often used more than one year, but occasionally a pair will switch to a new nest tree within their home range (Forsman 1980). One to three eggs, usually two, are laid in March or April. The female incubates the eggs and broods the young, while the male provides most of the food for the female and young (Forsman 1976, 1980). After leaving the nest in May or June, the young are fed by both parents until August or September. The young become independent in September or October, at which time they disperse from the parental nest areas (Forsman 1976, 1980).

Spotted owls may not nest every year. In Oregon the percentage of the population nesting each year from 1972 to 1974 ranged from 16 to 89 (Forsman 1976). Why some pairs refrain from breeding in some years is unknown.

Nesting Habitat

Multilayered old-growth forests are the preferred nesting habitat of spotted owls in Oregon and Washington. Of 47 nests examined by Forsman between 1972 and 1980, 42 were in old-growth forests, 2 were in stands dominated by large mature trees (100-140 years old), and 3 were in forests containing scattered old-growth trees but where the majority of trees were 70 to 80 years old. Within groves of trees surrounding nest sites of spotted owls, canopy closure usually averaged at least 70 percent. Nests were found on north, east, south and west aspects as long as suitable forest stands were available (Forsman et al. 1984). Nests were usually located within 1,000 feet of a spring or stream but were occasionally found as far as 1 mile from water (Forsman 1976).

Figure 6.—A spotted owl nest in a large cavity that was formed when a limb ripped loose from the trunk of an old-growth Douglas-fir, exposing the hollow interior of the trunk.

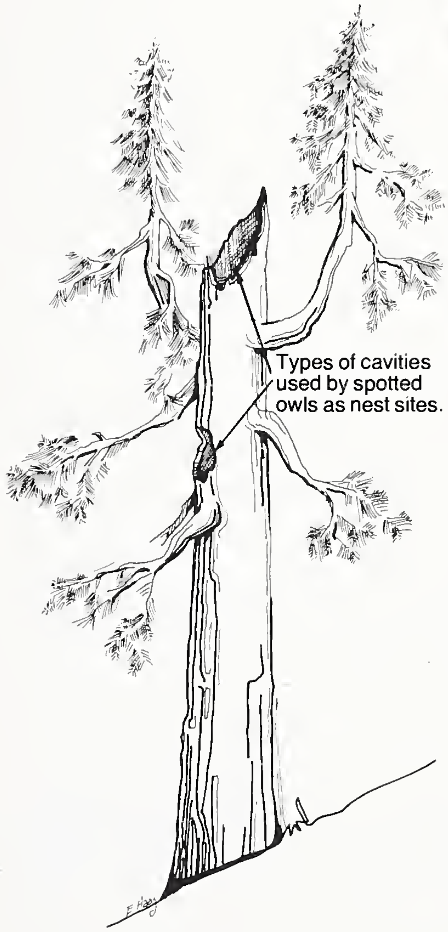


Figure 5.—In western Oregon and Washington, most spotted owls establish their nests in old-growth trees in cavities created by structural damage and decay.

All nests found in Oregon and Washington were in trees. Of the 47 nests in Oregon, 30 were in cavities in old-growth conifers (figs. 5 and 6) and 15 were in clumps of deformed limbs caused by dwarf mistletoe infection or in old stick platforms that had been constructed by other species of birds or by mammals. Two nests were in platforms formed by natural accumulations of moss and other debris on top of large limbs in old-growth trees. In temperate and high temperate conifer forests, most nests were in cavities, but in mixed conifer forests, nests were about equally divided between cavities and the other types mentioned above (Forsman et al. 1984). Forsman (1976) reported that nestling mortality was higher in platform nests than in cavity nests.

Because spotted owls require much larger cavities for nesting than those created by woodpeckers, they depend on cavities that develop from heart rot and structural breakage. Cavities selected for nests are usually inside the broken top of an old-growth tree or in a hole where a large limb has ripped loose from the bole of the tree, exposing the hollow interior (figs. 5 and 6). Living trees are preferred for nesting, as is indicated by the fact that 45 of the 47 nests found in Oregon have been in live trees (Forsman et al. 1984).

Roosting Habitat

In addition to a suitable nest site, spotted owls require forested areas for roosting during the day. They normally roost low in the forest understory during warm or hot weather, and high up in old-growth or mature trees during cold, wet weather (Barrows 1980; Barrows and Barrows 1978; Forsman 1976, 1980, 1981). The area within several hundred yards of the nest is heavily used for roosting; many other roosts are scattered throughout the foraging area.

On two study areas in western Oregon, Forsman (1980, 1981) found that spotted owls roosted in old-growth forests 91 and 97 percent of the time. Forests younger than 35 years were infrequently used for roosting. These studies suggested that old-growth forests were preferred for roosting because large trees provide the most protected roosts during cold rainy weather, and multi-layered canopies provide the coolest roosts during warm weather.

Foraging Habitat

Radiotelemetry studies in western Oregon have shown that spotted owls forage primaily in old-growth and mature forests, and avoid clearcuts and young second growth (Forsman 1980, 1981). A variety of small mammals are utilized as prey. The most important items in the diet in terms of biomass are the northern flying squirrel and the dusky-footed woodrat (table 1) (Forsman 1976, 1980, 1981).

Woodrats predominate in the diet in mixed conifer forests, whereas flying squirrels predominate in temperate and high temperate conifer forests. Forsman (1980) suggested that spotted owls in temperate and high temperate conifer forest avoided clearcut areas at least partly because their preferred prey, flying squirrels, do not normally occur in clearcut habitats (Gashwiler 1959).

Table 1—Diet of spotted owls in temperate and mixed conifer forests in Oregon[1]

Prey Species	Temperate Conifer forest	Mixed conifer forest
	Percent	
Northern flying squirrel:		
Occurrence	42	18
Biomass	57	14
Woodrat:		
Occurrence	2	39
Biomass	7	70
Red tree vole:		
Occurrence	13	5
Biomass	4	1
Red-backed vole:		
Occurrence	9	9
Biomass	2	2
Deer Mouse:		
Occurrence	9	5
Biomass	2	1
Snowshoe hare/brush rabbit:		
Occurrence	2	3
Biomass	16	6
Other mammals:		
Occurrence	16	13
Biomass	10	3
Birds:		
Occurrence	3	6
Biomass	2	3
Reptiles:		
Occurrence	T	0
Biomass	T	0
Insects:		
Occurrence	4	2
Biomass	T	T

T = trace

[1] Data are summarized from 817 spotted owl prey items from temperate conifer forests on the west slope of the Cascade Range and 654 spotted owl prey items from mixed conifer forest in the Siskiyou Mountain area (Forsman et al. 1984).

Two radiotelemetry studies of the foraging behavior of spotted owls in western Oregon revealed that foraging areas used by individual owls ranged from 1,350 to 8,350 acres (Forsman 1980, 1981). The majority of individuals used areas of 2,270 to 3,460 acres for foraging (fig. 7). The minimum amount of old-growth forest in the combined foraging areas of a pair of radio-tagged owls was 1,008 acres, and the minimum amount of old-growth in the foraging area of one individual was 740 acres. Whether the above minimal amounts of old-growth are adequate to support breeding pairs of spotted owls over long periods has not been determined; there are no data to suggest that smaller amounts of old growth may be suitable.

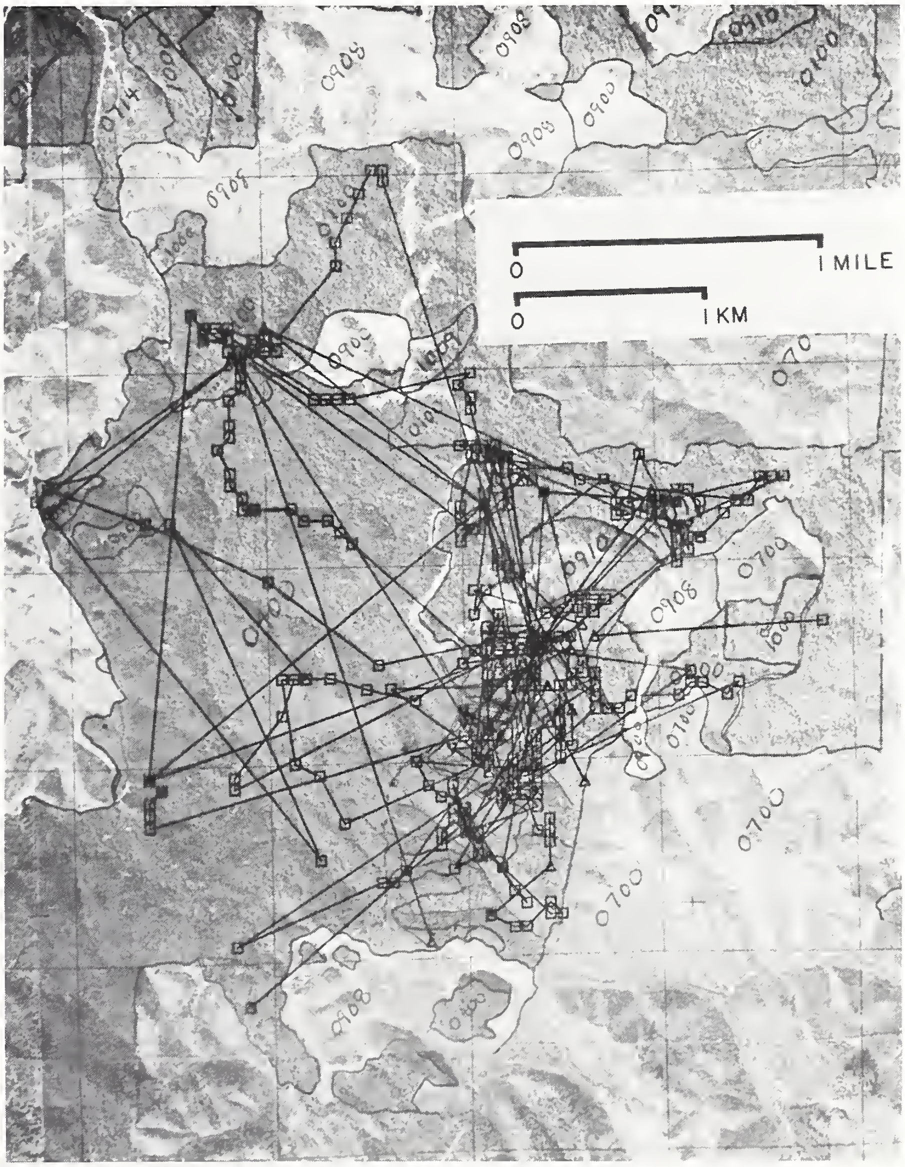


Figure 7.—Spotted owls in western Oregon showed a strong preference for old-growth and mature forests for foraging and roosting; they avoided recent clearcuts, burned areas and young second growth. This photo shows a computer map of the movements of a radio-tagged spotted owl during a 4-month period. Numbers on the photo indicate cover types used for an analysis of habitat selection.

Management Considerations

For spotted owl populations to be maintained on commercial forest land in Oregon and Washington, old-growth forest habitat must be replaced as existing old-growth stands are harvested. Replacement old-growth stands should have all the characteristics found in existing old-growth stands. On most sites it will probably require 175 to 200 years to develop stands with the structural characteristics necessary for nesting (Forsman 1976, Franklin et al. 1981).

Development of a management plan for the spotted owl in Oregon and Washington has been undertaken by the Oregon-Washington Interagency Wildlife Committee (O-WIWC), a group of biologists representing the USDA Forest Service, the Bureau of Land Management and the Fish and Wildlife Service of the U.S. Department of the Interior, the Oregon Department of Fish and Wildlife, the Washington Department of Game and other government agencies. This committee recognized that it would not be economically feasible to provide enough old-growth habitat for all known pairs of spotted owls; therefore, the O-WIWC recommended that state and federal management agencies manage for a reduced but genetically viable population of owls, with pairs distributed as evenly as possible throughout the known range of the species.

In Oregon, the O-WIWC plan recommended that enough old-growth habitat for 400 pairs of spotted owls be managed on federal and state lands. This management plan would allow a reduction of about two-thirds in the existing population under the assumption that most pairs outside managed areas will eventually be eliminated. In developing the plan, the committee assumed that some of the 400 managed pairs could be located in wilderness, roadless, or other areas where constraints on timber management were already established or anticipated. They also emphasized, however, that maintaining an even geographic distribution of pairs on forest lands should be the principal criterion for selection of management sites.

A minimum of 400 managed pairs was selected for Oregon because that was estimated as the number of pairs required to maintain an evenly distributed population with pairs (or clusters of several pairs) spaced at intervals of 3 to 12 miles. Wider spacing of pairs was considered undesirable because the number of juveniles dispersing across large areas of inhospitable habitat would be limited, and those doing so would be more susceptible to predation. Vacancies among breeding pairs might go unfilled if the pairs were spaced at wider intervals. The 400 pairs also appeared adequate from a genetic standpoint (Soule and Wilcox 1980).

At each of the 400 sites selected for management, the O-WIWC plan recommended that at least 300 acres of old-growth forest be retained around the nest area of each managed pair and that an additional 700 acres of old-growth, or the oldest available forest, be retained within 1.5 miles of the nest site. The 1.5-mile radius was used because nesting radio-tagged spotted owls rarely forage further than this from their nests (Forsman 1980). The unstated assumption in this plan is that old-growth stands maintained for spotted owls will eventually be harvested when replacement old-growth stands are regenerated on adjacent sites. The O-WIWC plan recommended that replacement old-growth stands be managed so that stand structure and species composition duplicate as closely as possible the structure and species composition of old-growth stands already occupied by spotted owls on each site. The committee also recommended that no salvage logging be conducted in old-growth stands occupied by spotted owls. The latter recommendation was made because salvage logging in old-growth stands in western Oregon and Washington frequently causes additional tree mortality (Twomby 1982, personal communication) and reduces the number of potential nest trees for spotted owls and their prey.

A major omission in the management plan for spotted owls in Oregon is any discussion concerning the disposition of pairs not included in the 400 pairs selected for management. Presumably, these pairs will receive no special management consideration. In some cases, however, it may be possible to provide "unmanaged" pairs with at least short-term protection by making alterations in timber harvest units, such as changing boundaries to avoid cutting nesting or roosting sites.

Although the spotted owl management plan proposed by the O-WIWC is not intended as a general old-growth management plan for western Oregon, it will provide a network of old-growth reservoirs for other species of wildlife that find their optimum habitat in moderate to low elevation, old-growth forests. Species that will benefit include the bald eagle, pileated woodpecker, goshawk, Vaux's swift, and a variety of cavity-nesting birds and mammals. As soon as enough basic data are available for the state of Washington, the O-WIWC hopes to formulate a management plan for spotted owls in Washington that will be similar to the plan developed for Oregon. California has already adopted a similar plan.

Information Needs

From a management standpoint, there are several areas where additional information is needed. The most pressing is to determine how much old-growth or mature forest is required to support a breeding pair of spotted owls. This is a difficult problem because it requires a comparison of rates at which owls reproduce and survive in areas with different amounts of old-growth and mature forest. The only way this can be accomplished is through long-term monitoring of both the owls and their habitat.

In order to measure the effectiveness of management programs, trends in spotted owl populations need to be monitored. State and Federal management agencies should conduct a complete inventory on state and federal lands in Washington and Oregon to obtain baseline data that can be used to evaluate future population changes. Trends could then be determined by checking selected areas at regular intervals to see if owls are present and by conducting regular calling counts on established transects.

Information is needed on the dispersal and survival of juvenile spotted owls to determine if dispersal and recruitment of widely spaced pairs will be adequate to maintain the population. At present, management recommendations for maximum spacing distances between pairs are based on "best judgment" rather than on actual data.

Studies should be conducted to determine how intensive forest management affects populations of major prey species used by spotted owls. Without data on abundance of prey in different forest age classes, it is difficult to evaluate the relative suitability of these age classes as foraging habitat for owls (Forsman 1980, 1981).

Additional study is also needed on habitat selection by spotted owls. Research started in Washington in 1982 and ongoing studies in California will complement work that has been conducted in Oregon and will considerably increase our understanding of habitat selection by spotted owls.

References Cited

Barrows, C. Summer roost selection by spotted owls; an adaptation to heat stress. Long Beach, CA: California State University; 1980. 51 p. Thesis.

Barrows, C.; Barrows, K. Roost characteristics and behavioral thermoregulation in the spotted owl. Western Birds 9(1): 1-8; 1978.

Bent, A. C. Life histories of North American birds of prey. Part 2. Smithsonian Institution, U.S. National Museum Bull. 170. 1938. 482 p.

Forsman, E. D. A preliminary investigation of the spotted owl in Oregon. Corvallis, OR: Oregon State University: 1976. 127 p. Thesis.

Forsman, E. D. Habitat utilization by spotted owls in west-central Cascades of Oregon. Corvallis, OR: Oregon State University: 1980. 95 p. Dissertation.

Forsman, E. D. Habitat utilization by spotted owls on the Eugene District of the Bureau of Land Management. Tech. Rep. Portland, OR: U.S. Department of the Interior, Bureau of Land Management; 1981. 63 p.

Forsman, E. D.; Meslow, E. C.; Wight, H. M. Biology and management of the spotted owl in Oregon. Washington, D.C.: The Wildlife Society; Wildlife Monograph. 87; 1984. 65 p.

Forsman, E. D.; Meslow, E. C.; Strub, M. J. Spotted owl abundance in young versus old-growth forests, Oregon. Wildl. Soc. Bull. 5(2): 43-47; 1977.

Franklin, J. F.; Cromack, K. Jr.; Denison, W. [and others]. Ecological characteristics of old-growth Douglas-fir forests. Gen. Tech. Rep. PNW-118. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 48 p.

Garcia, E. R. A survey of the spotted owl (*Strix occidentalis*) in Washington. In: Schaffer, P.; Ellers, S. eds. Owls of the west: their ecology and conservation: Proceedings of a symposium; 1979. Tiburon, CA: National Audubon Society, Western Education Center; 1979: 18-28.

Gashwiler, J. S. Small mammal study in west-central Oregon. J. Mammal. 40(1): 129-139; 1959.

Gould, G. I., Jr. The status of the spotted owl in California. Tech. Rep. Sacramento, CA: California Department of Fish and Game; 1974. 36 p. + 20 p. appendix.

Gould, G. I., Jr. Distribution of the spotted owl in California. Western Birds. 8(4): 131-146; 1977.

Gould, G. I., Jr. Status and management of elf and spotted owls in California. In: Schaffer, P.; Ellers, S., eds. Owls of the west: their ecology and conservation: Proceedings of a symposium; 1979. Tiburon, CA: National Audubon Society, Western Education Center; 1979: 86-87.

Marcot, B. G.; Gardetto, J. Status of the spotted owl in Six Rivers National Forest, California. Western Birds. 11: 79-87; 1980.

Marshall, J. T., Jr. Food and habitat of the spotted owl. Condor. 44(2): 66-67; 1942.

Postovit, H. A survey of the spotted owl (*Strix occidentalis*) in northwestern Washington. Report to: National Forest Products Association, Washington, DC: 1979. 15 p.

Reichard, T. A. Barred owl sightings in Washington. Western Birds 5: 138-140; 1974.

Soule, M. E.; Wilcox, B. A., eds. Conservation biology: an evolutionary-ecological perspective. Sunderland, MA: Sinauer Assoc. Inc.; 1980. 395 p.

Taylor, A. L., Jr.; Forsman, E. D. Recent range extensions of the barred owl in western North America, including the first records for Oregon. Condor. 78: 560-561; 1976.

Twomby, A. D. Personal communication. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, OR. 1982.

U.S. Department of Agriculture, Forest Service. Unpublished data on file at Pacific Northwest Region, Portland, OR.

U.S. Department of the Interior, Fish and Wildlife Service. The northern spotted owl - a status review. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service; 1982. 29 p.

13

Bald Eagles

Mark V. Stalmaster
Richard L. Knight
Barbara L. Holder
Robert J. Anderson

Table of Contents

Introduction

Bald eagles inhabit the forests of Oregon and Washington during both the wintering and nesting seasons. They are most abundant during the winter when there is an influx of birds from the north, but there also are substantial spring and summer nesting populations. Forest managers often are faced with the challenge of maintaining wintering and nesting habitat within Pacific Northwest forest ecosystems for these eagle populations.

Bald eagles still occupy most of their historic range in the northwest, but populations have been steadily declining for many years. It is only recently that this decline has slowed or stopped. Braun et al. (1975) and Lincer et al. (1979) have identified habitat alteration, especially along shorelines, as one of the primary factors contributing to declines in bald eagle populations. Other factors include poisoning of both prey species and eagles themselves by pesticides and pollutants, and direct mortality resulting from a variety of causes (Lincer et al. 1979).

Eagles have fared better in Oregon and Washington than in most areas, and substantial populations still exist. Recent surveys indicate that over 200 breeding pairs and about 2,000 wintering birds occur in the two states (table 1). In Washington the majority of the birds are found in west-side forest areas, while in Oregon, the largest concentration is found in the Klamath Basin in the south central part of the state. Sanctuaries such as the Skagit River Bald Eagle Natural Area in Washington and the Bear Valley National Wildlife Refuge in Oregon have been established to protect important habitat for eagles.

Bald eagles are classified as endangered in all but five states of the contiguous United States by the Fish and Wildlife Service (U.S. Dept. of the Interior 1978). In Oregon, Washington, Minnesota, Michigan, and Wisconsin they are listed as threatened. The threatened classification indicates the species could potentially become endangered in the near future. Because the bald eagle is classified as threatened, both federal and state regulations mandate special considerations be given to the habitats used by this species.

In addition to the Endangered Species Act, bald eagles are protected at the federal level by the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act. They also are protected by state law in both Oregon and Washington. The Endangered Species Act requires that all federal agencies protect and manage bald eagles and their habitat where they occur on federal lands. The Bald and Golden Eagle Protection Act is broader and states that "no person shall take . . . any bald eagle, . . . alive or dead, or any part, nest or egg thereof . . ."; and it further states that "take" also includes "to pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest, or disturb . . .". Concern for the well-being of eagles, as evidenced by land preservation, protective legislation, and public support, is widespread.

Timber harvesting is extensive throughout western Oregon and Washington. In areas used by eagles, harvesting operations often conflict with the habitat requirements of eagles. Failure to recognize the habitat needs of eagles when implementing timber management programs can result in deterioration of their habitat. Properly designed silvicultural and harvesting methods, however, can maintain or possibly improve habitat for existing populations and could create new habitat for future populations. Recognition of eagle habitat requirements by land managers in planning forest management activities will have a major influence on whether populations of bald eagles in Oregon and Washington decline, remain stable, or increase in the future.

This chapter discusses the resource requirements of nesting and wintering bald eagles in Oregon and Washington and outlines management techniques known to be effective in protecting and enhancing their habitat. Although foraging habitats are important in the overall requirements of eagles, they are less apt to be impacted by forestry-related activities than nesting, roosting or perching habitats. Consequently, these latter habitats have received priority in the discussion.

Table 1—Wintering and nesting counts of bald eagles in Oregon and Washington

Winter counts		
Year	OR 1/	WA 2/
1979	494	1126
1980	653	1624
1981	547	1611

Nest counts	OR 3/	WA 4/
Nesting territories	147	144
Occupied territories	101	114

1/ After Opp (1980)
2/ After Knight et al. (1981).
3/ In 1982 after Isaacs et al. (1983).
4/ In 1975 after Grubb (1980).

Identification

Adult bald eagles are easily recognized by their conspicuous white head and tail on a dark body. Adult plumage is not acquired until they are 4 to 6 years old. Young bald eagles, however, are often mistaken for golden eagles because they are dark without the white head and tail. Golden eagles are distinguished from bald eagles by the presence of completely feathered legs, distinct white patches on the tail and beneath the wings on subadults, and a golden coloration on the back of the head on adults. Several plumage patterns of subadult bald eagles exist, but variability can be quite high with white mottling occurring irregularly. The osprey frequently occurs in habitat similar to that of bald eagles but is smaller, has a conspicuous white breast and a black patch at the crook in the wing.

Nesting Habitat

Suitable nesting habitat is essential for successful reproduction in bald eagle populations. In both Oregon and Washington, extensive research has been conducted to determine elements of eagle nesting habitat (Anthony et al. 1982, Grubb 1980). This research has shown that nesting eagles exhibit a strong preference for large, dominant or condominant trees in a heterogeneous stand of mature or old-growth coniferous timber. With some raptor populations, it has been shown that a lack of suitable nest sites is a limiting factor in population growth (Newton 1979:264). Whether this is true for bald eagles has not been determined and will require additional research, particularly in areas where their preferred habitat has been or is being altered. In the meantime, efforts should be directed toward maintaining sites containing the known elements of preferred bald eagle nesting habitat.

Territory Size

Nesting pairs of bald eagles (fig. 1) establish territories of considerable size. Territory sizes can be determined by

Figure 1.—Nesting pair of bald eagles.

monitoring local movements of the nesting pair during the breeding season. This is, however, very time consuming, and reasonable estimates can be obtained by measuring distances between occupied nests in areas with large breeding populations.

In the San Juan Islands in western Washington, Grubb (1980) found that the average territory had a radius of 1.0 miles. Studies of 136 (Corr 1974) and 2760 (Robards and Hodges 1977) eagle nests in southeast Alaska showed an average spacing of 1.25 and 1.1 miles between nests, respectively, in what may be a saturated nesting area. Differences in terrain, vegetation, and food availability all contribute to considerable variation in the shape and size of individual territories. The actual territory defended probably is limited to a much smaller area in situations where nesting and foraging activities are concentrated, especially along shorelines.

Alternate Nests

Bald eagles often construct more than one nest in a territory. Nests other than the active nest are called alternates. The function of these alternate nests is not conclusively known. The breeding pair may use an alternate nest to reproduce if the active nest is disturbed or destroyed thereby preventing an unsuccessful nesting effort (Newton 1979:89), but this is not well documented. Use of alternate nest sites is not limited just to those times when the active nest is destroyed. Pairs often naturally change between two or more nests within a territory from year to year. This may have an evolutionary function to reduce susceptibility to nest parasites or perhaps predators, to promote nest security, or to minimize negative impacts of nesting on the nest tree and adjacent resources. In addition, an alternate nest may be a visual signal indicating the boundaries of the territory to other eagles, may play a role in courtship and pair bonding, or fresh material placed in nests may signal that the territory is occupied.

Grubb (1980) found that 54 of 144 (38 percent) territories in western Washington had altenate nests, usually numbering one or two. The distance of alternate nests from the active nest ranged up to 1.2 miles, with an average distance of 1050 feet.

Nest Location

Bald eagles usually nest in trees near large bodies of water which allows easy access to their preferred diet of fish. In western Washington, Grubb (1980) found that the average distance of 218 nests from water was 282 feet and ranged from 15 to 2640 feet. Fifty-five percent of these nests were within 150 feet of a shoreline and 92 percent were within 600 feet (fig. 2A). In an earlier study, Grubb (1976) found 94 of 100 nests were associated with a saltwater shoreline. Irregularity of shorelines increases the amount of forest/water edge, which provides optimal habitat for nesting birds.

In Oregon, the 155 nests recorded occurred in three major geographic areas: along the coast and lower Colum-

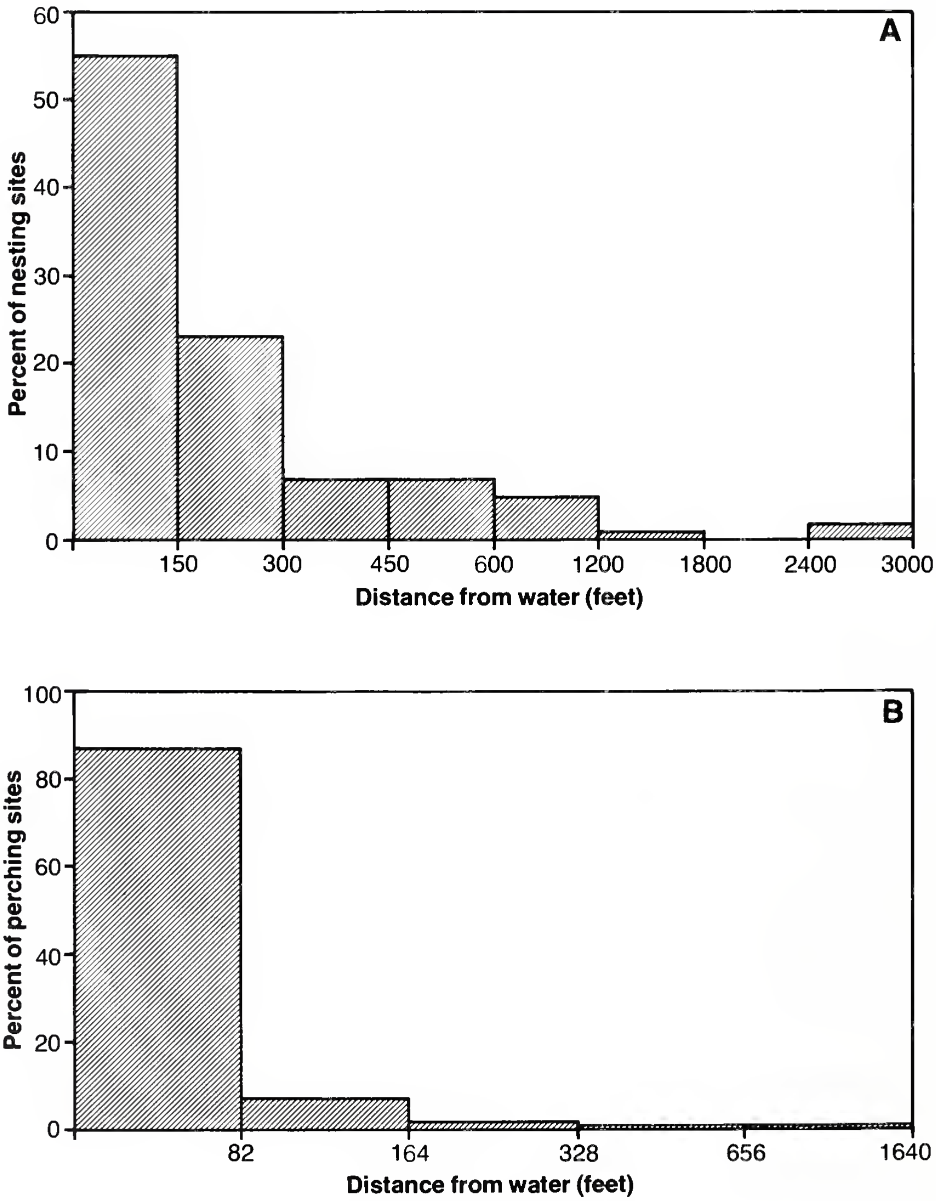


Figure 2.—Average distances of nesting sites (A) and perching sites (B) from large bodies of water in Washington (after Grubb 1976, Hunt et al. 1980).

bia River (20 percent); in the Cascade Mountains (25 percent); and in the Klamath Basin (55 percent). Nests along the coast and lower Columbia River, in the Cascade Mountains, and in the Klamath Basin averaged 413, 371, and 141 feet from water, respectively (Anthony and Isaacs 1981). Eighty-five percent of these nests were located within one mile of major bodies of water (Isaacs et al. 1983).

Nest Tree Selection

Tree species

Selection of tree species for nesting by bald eagles varies with the geographic and vegetative type of the region (table 2). In western Washington, Grubb (1976) found that 70 percent of 218 nests were located in Douglas-fir trees, 17 percent in Sitka spruce, and the remaining 13 percent in other species. More recent data (Allen 1981) on nests in western Washington show similar trends with Douglas-fir (84 percent) and Sitka spruce (12 percent) predominantly being used. In coastal Oregon, nest tree use was found to be similar to Washington, with Douglas-fir (74 percent) and Sitka spruce (23 percent) again predominating. In the Cacade Mountains and the Klamath Basin, ponderosa pine was the most widely-used species (87 and 79 percent, respectively) followed by Douglas-fir (8 and 15 percent, respectively) (Anthony and Isaacs 1981).

Tree Structure and Forest Stand

When eagles select trees for nesting, tree structure and associated forest stand characteristics appear to be more important than tree species (Anthony et al. 1982). Growth forms of nest trees usually differ from the surrounding stand in that they tend to be taller, are of larger diameter, and often extend above the canopy (fig. 3A). In western Washington, 112 nest trees surveyed by Allen (1981) averaged 120 feet in height and 53 inches in d.b.h. Anthony and Isaacs (1981) found a similar trend in Oregon; average height and d.b.h. of nest trees along the coast, in the Cascade Mountains, and in the Klamath Basin were 191 feet and 69 inches, 134 feet and 46 inches, and 124 feet and 41 inches, respectively. These d.b.h. values were between 113 and 150 percent greater than the average for surrounding stands. Nest trees in Oregon tended to be either dominant (63 percent) or codominant (37 percent) in the stand (Anthony and Isaacs 1981). Nest trees in Washington also were primarily dominant (29 percent) or codominant (70 percent), with only 1 percent suppressed (Grubb 1976).

Examination of nest sites has shown that bald eagles prefer old-growth or mature second-growth forests for nesting (Anthony et al. 1982). Height and d.b.h. of nest trees are characteristically larger than the minimums specified by the USDA Forest Service in defining old-growth stands. Although stands are usually mature or old-growth, many are seral communities. Douglas-fir, an important nest tree species, is an example of a seral species which, in the absence of disturbance, will eventually be succeeded by other conifers (Franklin and Dyrness 1973).

Table 2—Percent of tree species used by bald eagles for nesting in Oregon and Washington

	WA nest trees				OR nest trees 3/			
	1975 1/		1981 2/		Coastal		Inland	
Species	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Douglas-fir	153	70	94	84	23	74	16	13
Sitka spruce	37	17	13	12	7	23		
Western hemlock	10	4			1	3		
Grand fir			4	4				
Western red cedar	1	1						
Ponderosa pine							101	81
Sugar pine							5	4
Other true firs							2	2
Black cottonwood	6	3	1	1				
Others	11	5						

1/ After Grubb (1976).
2/ After Allen (1981).
3/ After Anthony and Isaacs (1981).

Grubb (1976) found that 95 percent of the nest trees used by eagles in Washington were alive: 48 percent had either broken or dead tops—and 47 percent had living, intact tops. Trees which forked or grew irregularly were preferred, as were trees with an open structure allowing easy access to the nest. Foliage was often present above the nest. Nests in western Washington occurred an average of 11.5 feet below the top of the tree (Grubb 1976).

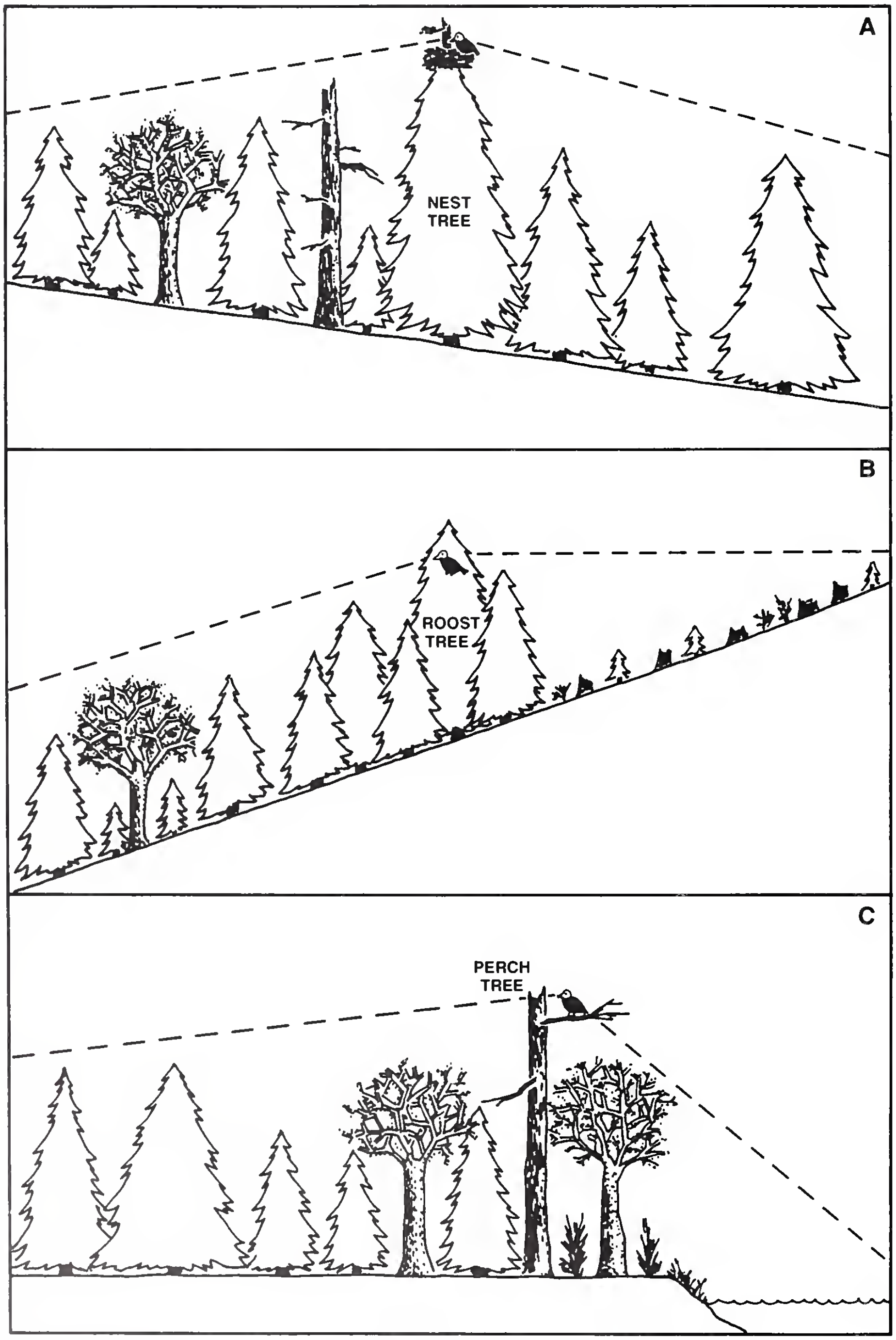


Figure 3.—Bald eagle nest (A), roost (B), and perch trees (C) usually are situated in the stand where visual access to adjacent habitat is possible. Trees emerging above the canopy or on edges of clearings are selected.

Bald eagles typically nest in structurally heterogeneous forest (uneven-aged) stands (fig. 4) (Grubb 1976) and avoid even-aged stands that have a continuous unbroken canopy. Crown closures range from 10 to 70 percent (Anthony and Isaacs 1981). Most nesting stands (69 percent) in western Washington are coniferous, with pure hardwood forests rarely being used (fig. 5).

Nests

Bald eagle nests usually can be recognized by their large size, their proximity to water, and by food debris consisting of at least some fish remains below an active or recently active nest. Osprey nests are similar to bald eagle nests, but they generally are smaller, more rounded in appearance, and in most cases, are located directly on top of the nest tree. The nests of bald and golden eagles are often similar, but Anderson and Bruce (1980) found several distinguishing characteristics. Bald eagle nests were larger in diameter (4.9 to 7.9 feet) than golden eagle nests (3.9 to 4.9 feet), were located in the interior of forest stands in trees extending above the canopy, and were in close proximity to water. Nests of golden eagles were found near the edge of a stand next to a clearcut or opening, were located in trees below the overall canopy level, and were not associated with water.

Figure 4.—Bald eagles typically nest in structurally heterogeneous stands of mature and old-growth forest. A snag adjacent to the nest tree is a desirable characteristic.

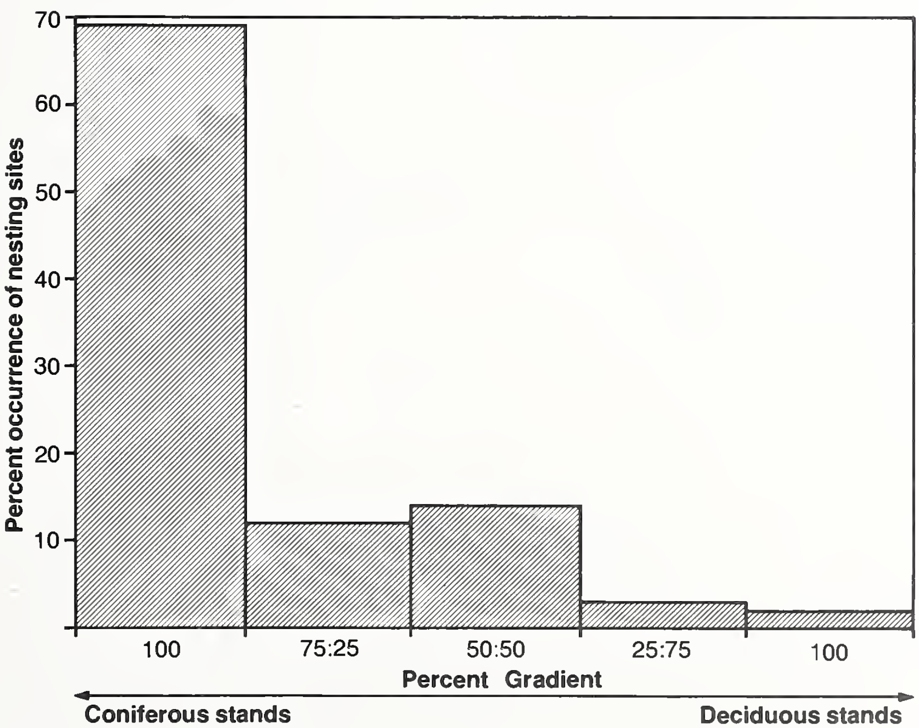


Figure 5.—Most stands used for nesting by bald eagles in Washington are coniferous (after Grubb 1976).

Roosting Habitat

Roosts are areas where eagles spend the night, but they also are used to a lesser extent during the daytime, especially during severe weather conditions. Many roosting sites are traditionally used year after year. Hansen et al. (1980), working in northwest Washington, described four characteristics of winter roosts or potential roosts. These were: a clear line of sight to surrounding terrain; a favorable microclimate; stout perches high above the ground; and freedom from human activity.

Roosts are usually found by observing and following eagles during roosting flights at dusk. Where direct observation is ineffective, attaching radio transmitters to eagles and tracking their movements is a valuable technique for locating roosts.

Communal Roosts

Bald eagles often roost in large groups. Communal roosting by wintering eagles is common, but non-breeding eagles also may roost together during spring and summer. In surveys of five communal roost sites in the Klamath Basin, over 500 eagles were counted, representing one of the largest concentrations in the United States (Keister 1981). Ward and Zahavi (1973) speculated that communal roost sites of birds serve as areas where information regarding food location is exchanged. Evidence is available suggesting that eagles follow each other when leaving roosts to forage, and this enables them to acquire information regarding the location of food sources (Knight 1981). Conspicuous assembly trees, called staging areas, may occur between roosts and feeding sites, and serve to attract other eagles to roosts (Hansen et al. 1980). Communal roosts also may have a function in establishing or maintaining pair bonds.

Roost Site Selection

Winter roost site selection appears to depend more on protective landforms and availability of coniferous forests than on proximity to water. Coniferous roosts are important to eagles for protection from adverse weather (Hansen et al. 1980, Stalmaster and Newman 1979), but eagles also may use deciduous

roosts especially in riparian habitat. Wind, air temperature, rain, and long-wave radiation are less severe in coniferous roosts than in deciduous stands or in open areas in both Washington and Oregon. By roosting in conifers, eagles are able to reduce the amount of energy expended to maintain a constant body temperature. Consequently, stress caused by severe weather conditions is less likely to occur (Keister 1981, Stalmaster 1981a). In addition, reduced energy expenditure at night also will reduce daytime food requirements, resulting in less competition where there is a limited food supply (Stalmaster 1981a).

Roosts often are located on leeward, northeast slopes or in depressions or valleys which are protected from wind. These characteristics of roosts have been observed both in Washington (Hansen et al. 1980) and in the Klamath Basin area of southern Oregon and northern California (Keister 1981). In Washington, known communal roosts were 0.3 to 0.6 miles from water, but in the Klamath Basin, distances of roosts from water were found to be as far as 9 miles. Roost size is highly variable with sites in Washington ranging from 4 to 19 acres and those in the Klamath Basin ranging from 20 to 630 acres.

Selection of roost tree species by eagles varies, depending on availability and structural characteristics of the tree and the stand. Douglas-fir and black cottonwood are most frequently used in Washington, but western red cedar, bigleaf maple, and snags also provide roosting sites (Hansen et al. 1980, Hunt et al. 1980, Servheen 1975, Stalmaster 1976). Ponderosa pine, Douglas-fir, incense cedar, and "white" fir were the most often used roost tree species in the Klamath Basin of Oregon (Keister 1981).

As with nest trees, eagles use roost trees that are larger than the average size of trees in the stand, and these trees usually are mature or old-growth. In a survey of 11 communal roosts in the Pacific Northwest, Anthony et al. (1982) found that trees ranged from 131 to 311 years old and had heights and diameters larger than surrounding trees. Roost trees in five mixed conifer roosts in the Klamath Basin averaged 27 inches in diameter, compared to an average d.b.h. of 21 inches for adjacent trees (Keister 1981). Average height of roost trees was 92.5 feet. Mean height and d.b.h. of roost trees for communal roosts in Washington ranged from 81 to 104 feet and 22 to 23 inches, respectively, depending on location and species composition (Anthony et al. 1982). Roost trees usually extend well above the forest canopy.

Roost trees usually are selected so that visual access to adjacent habitat is possible (fig. 3B). Forest stands with a high percentage of trees with open structure are preferred (Keister 1981). These allow unobstructed views and provide open flight paths.

Breeding or Summer Season Roosts

Little data have been collected in the Pacific Northwest regarding the roosting habits of breeding and nonbreeding bald eagles during the spring and summer. In Minnesota, Pramstaller (1977) found that the nest tree was the center of roosting activity for both adults and fledglings, with most roost perches occurring within 1/4 mile of the nest. As the young developed, family members gradually roosted further from the nest tree.

Perching Habitat

Eagles spend a large portion of the day perching in trees (fig. 6). This occurs during both the nesting and wintering seasons. Studies have shown that wintering eagles (Stalmaster 1981a) and summering nonbreeding adults (Gerrard et al. 1980) perch more than 90 percent of the daylight hours. Perching occurs somewhat less for breeding adults since much of their time must be spent in parental care duties.

Perching Site Functions

The term "perching" does not adequately describe all of the possible functions of this behavior. Perching in prominent locations plays an important role in food acquisition since eagles often search and hunt from trees where they wait until prey passes within striking range. Consumption of prey items often occurs at favorite feeding perches. Perches also may serve as sites for display to attract potential mates, especially during the breeding season (Fraser 1981, Mahaffy 1981). Eagles may perch in conspicuous places to signal the occupation of a territory or to advertise the location of feeding and roosting areas. Breeding adults also use "sentry" perches for defending the nest. Perching on exposed branches also is beneficial in allowing the warming and drying of the plumage by the sun. This source of heat provides a supplemental energy source which can reduce metabolic demands (Hayes and Gessaman 1980). In addition, perching activity requires little expenditure of energy (Stalmaster 1981a).

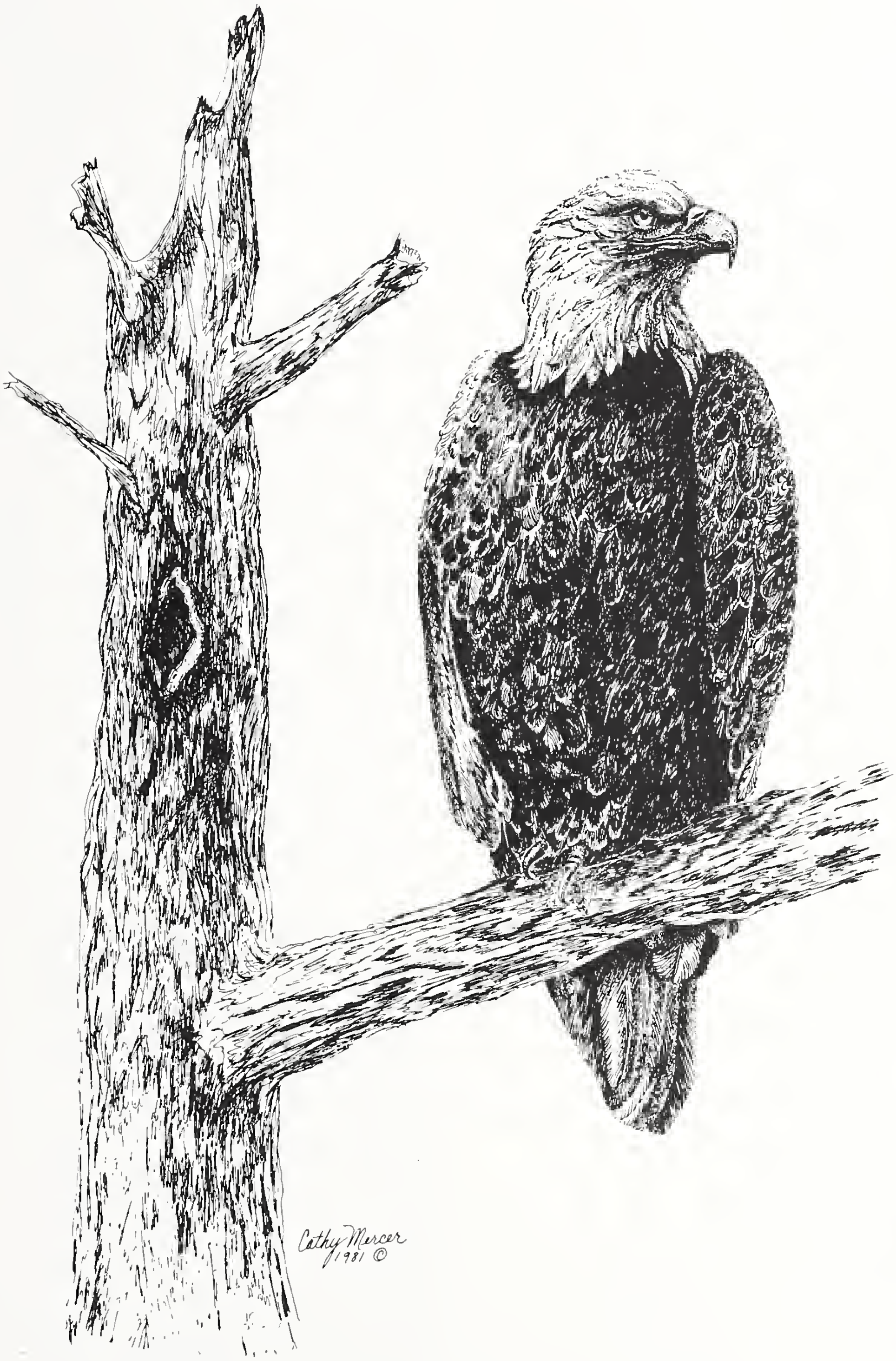


Figure 6.—Bald eagles spend a large portion of the day perching in trees, a behavior often called "loafing".

Perch Site Selection

Perching sites are closely associated with water and local food sources (fig. 7). Proximity to food is the primary factor influencing selection of winter perching sites. On the Skagit River in Washington, 87 percent of all wintering eagles were observed to perch within 82 feet of the river (fig. 2B) (Hunt et al. 1980). During the nesting season, perches often are close to the nest tree.

Important elements of perching sites include height and structure of the perch tree, occurrence on edges with proximity to open regions, and visual access to adjacent habitat (fig. 3C) (Stalmaster and Newman 1979). Eagles usually perch in the tallest trees on the edge of stands and select strong, lateral branches high in the crown. They will, however, use shorter perch trees in order to hunt at more productive feeding sites.

Figure 7.—Perching sites often are associated with riparian habitat close to food sources. Plumages of subadult bald eagles, such as the one shown here, vary considerably.

Snags are preferred by eagles as perching sites in winter (Stalmaster and Newman 1979), and when close to the nest tree, are favored for perching during the nesting season (fig. 4) (Forbis et al. 1977). Snags provide strong branches, and often have broken tops which allow a wide visual field. In western Washington, live bigleaf maple, black cottonwood, and Sitka spruce also are used for perching in winter (table 3) (Hansen and Bartelme 1980, Stalmaster and Newman 1979). Maples and cottonwoods are used because they often are the tallest tree species in riparian stands, and maples usually have stout branches high in the crown. Sitka spruce apparently is selected because of its occurrence close to water. Other species, especially red alder, are often used, but apparently are not preferred because of their low stature (Stalmaster and Newman 1979).

Structural heterogeneity, an important component of nesting and roosting habitat, also is important in the selection of perching habitat. Small groups of trees and trees emerging above the canopy are preferred over large stands of uniform height and composition (Stalmaster and Newman 1979). If available, trees with both vertical and horizontal edge are used. Dominance or codominance is a preferred element. Lone trees or small groups of trees, such as those growing on islands in river channels, often are selected by eagles.

Table 3—Tree species used by bald eagles for winter perches in western Washington in general order of preference

	Nooksack River 1/		Skykomish River 2/	
Species	Percent used	Percent available	Percent used	Percent available
Snags	10	1	32	1
Black cottonwood	44	22	41	19
Bigleaf maple	7	2	5	1
Conifers	13	16	17	16
Red alder	26	59	5	63

1/ After Stalmaster and Newman (1979).
2/ After Hansen and Bartelme (1980).

Foraging Habitat

Availability of food is a natural factor which can limit populations of raptors, (Newton 1979:61) including bald eagles (Sherrod et al. 1976, Stalmaster 1981a, 1981b). Habitat must provide an adequate food base if eagles are to survive and reproduce. Suitability of habitat, therefore, is dependent upon food availability.

Bald eagles are opportunistic scavengers and predators that feed on a variety of prey items. Feeding areas almost always are associated with rivers, lakes, and coastal shorelines where fish, waterfowl, seabirds, and invertebrates are preyed upon. Small and large mammals also may be included in their diet in some areas.

Foraging Methods

An important aspect of the foraging behavior of bald eagles is that the feeding activity of one individual attracts and stimulates feeding by others. This results in a "feeding frenzy", with large groups feeding at the same time and place. Observations have shown that eagles follow others to food sources (Knight 1981) and once a supply is found, stealing food is a common behavior (Stalmaster 1981a). It is hypothesized that this gregarious behavior of eagles (fig. 8) increases the

Figure 8.—The gregarious behavior of bald eagles may increase the chances of all flock members in locating food.

chances for all members of the flock to locate food (Hansen et al. 1980, Knight 1981, Servheen 1975, Stalmaster 1981a). When large numbers of eagles feed together, however, competition could limit food intake by younger, subordinate birds (Stalmaster 1981a).

Food Requirements

During winter, daily food requirements of bald eagles in western Washington vary from 10 to 17 ounces depending on the energy content of the food (Stalmaster 1981a, Stalmaster and Gessaman 1982). Eagles consuming prey with a low energy content, such as spawned-out salmon, require about 17 ounces each day. If waterfowl are eaten, consumption can be as low as 10 ounces since bird carcasses usually contain more energy per unit of weight. While information about food requirements of nesting bald eagles and their young is not available, it is known that a pair of golden eagles and their young require between 35 and 70 ounces daily (Collopy 1980, MaGahan 1967). Presumably, requirements would be similar for bald eagles. A constant food supply is more critical in the nesting season because young are less tolerant of food deprivation than adults. Stewart (1970) has shown that adult eagles can be starved for 16 days without apparent harm, except for a dramatic but temporary weight loss. In addition, the crop of an adult eagle can store up to two pounds of food, which allows fasting for several days while still meeting daily energy requirements (Stalmaster 1981a).

Forage Areas

Typically, the foraging habitat of bald eagles is in large open areas with a wide visual field (Stalmaster et al. 1979). Foraging below the forest canopy is uncommon and eagle diets rarely include forest dwellers. Thickly vegetated areas are little used as foraging habitats by eagles because long, unobstructed flight paths are required in order to become and stay airborne (Fraser 1981). Suitable perching trees near food sources are desirable although eagles can and do use other structures for perching, such as riprap or cliffs, and will sometimes rest on open ground as long as food is available (Knight et al. 1979, Wood 1980). Evidence suggests that feeding territories sometimes are established and defended both in summer (Mahaffy 1981) and in winter (Hunt and Johnson 1981). Foraging, however, does occur outside defended territories in both seasons.

Sensitivity to Disturbance

Human disturbance factors can seriously impact both nesting and wintering bald eagle populations. Tolerance of disturbance may vary between individual birds or groups of birds from one area to another, and from one season to another. Forest management activities, if not planned and executed with the needs of the birds in mind, can be a serious disturbance factor. Improved access resulting from these activities also can increase the potential for other types of human disturbance.

Nesting

Human activitiy near nest sites may result in reproductive failure by bald eagles. Potentially-disturbing activities are most critical during the egg-laying and incubation stages of nesting. As the young develop, the same type of activity may have a lesser impact (fig. 9) (Mathisen 1968). Eagles which incubate eggs without disruption are likely to produce more young than birds that are disturbed (Fraser 1981). Eagles that are disturbed and leave their nests may inadvertently break eggs or injure the young, and their prolonged absence could result in the chilling or overheating of eggs or young. Tenacity to a nest site is weakest in late winter or early spring when a pair first establishes a territory. Disturbance of even limited duration at that time may cause desertion of the site. Nest abandonment, however, can occur at any time as the result of frequent and persistent disturbance (Fyfe and Olendorff 1976).

Eagles vary considerably in their response to human activity. Some pairs tolerate constant activity near the nest, while others are not as tolerant and will abandon their nesting attempt. In Oregon, Anthony and Isaacs (1981) found a lowered nesting success and reduced productivity from nest sites adjacent to major roads or recently logged areas, compared to nest sites in undisturbed areas. In an evaluation of nest sites in Washington, Grubb (1980) found that unproductive nests averaged 240 feet from permanent human activity, while productive nests averaged 390 feet, suggesting that human presence does lower productivity. Relocation of nests away from shorelines where human activity is high to areas of less activity may be another response to disturbance (Anthony and Isaacs 1981, Fraser 1981, Thelander 1973).

Wintering

Wintering bald eagles also may be adversely affected by human activity (Knight 1981, Russell 1980, Servheen 1975, Skagen 1980, Stalmaster and Newman 1978). Stalmaster and Newman (1978) found that eagles in northwest Washington avoided areas of high human activity and their feeding behavior was disrupted by human presence. In the open, the average flight (flushing) distances of subadults and adults from humans were 325 and 645 feet, respectively, indicating that older birds were more sensitive to disturbance. Eagles were more tolerant of activities which were partially shielded from sight by vegetation, even though they were aware of the activity (fig. 10). Where a vegetative buffer was present between eagles and humans, flight distances were 125 feet for subadults and 215 feet for adults, a 62 and 66 percent reduction, respectively, from flight distances in the open.

Figure 9.—Disturbance to bald eagles is most critical during the egg-laying and incubation stages of nesting and less important as the young develop, but the best strategy is to keep disturbance to a minimum until the young have fledged.

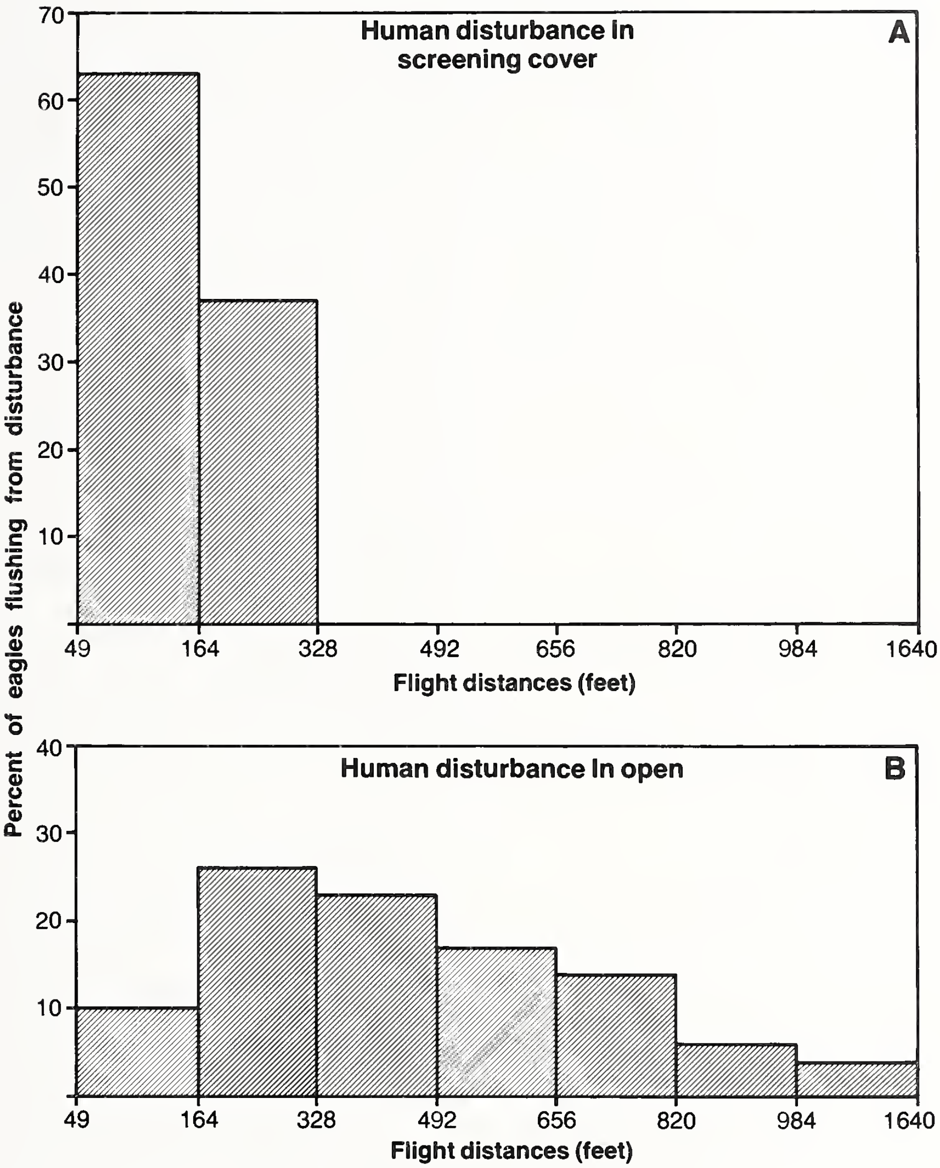


Figure 10.—Bald eagles are more tolerant of human activities when screening cover is present (A) than in the open (B) even though they are initially aware of the activities at similar distances (after Stalmaster and Newman 1978).

Knight (1981) observed that the average flight distance from canoeing activity was longer when eagles were flushed from river bars or banks (700 feet) than when flushed from trees (390 feet). Eagles on the ground, either feeding or standing, were more sensitive to human activity. Approximately 43 percent of all eagles flew to avoid the canoe activity, but variation was considerable depending on food availability and habituation to humans. Disturbances which cause avoidance flights not only restrict habitat use and alter behavioral patterns, but also cost the additional energy expended in flight (Stalmaster 1981b).

Some degree of habituation to winter activities occurs (Russell 1980, Stalmaster and Newman 1978) especially when competition for short food supplies overrides the eagles' natural wariness (Skagen 1980). Human activity in areas where eagles feed, however, creates a particularly stressful situation that is deleterious to the birds (Servheen 1975, Stalmaster 1981b). Disturbance associated with the noise of logging of stands adjacent to roosts did not cause desertion in subsequent years (Hansen et al. 1980). Minor levels of noise usually are not disruptive to the normal behavior of eagles except when they are in association with visual activities (Stalmaster 1976).

Management Considerations

Land managers should be aware that the Endangered Species Act of 1973, as amended (U.S. Department of the Interior, Fish and Wildlife Service 1978a), establishes special procedures that must be followed any time an action by or authorized by a federal agency will effect a threatened or endangered wildlife species.

Since the bald eagle is classified as "threatened" in Oregon and Washington, these requirements apply to forestry programs on federal lands in any area where such programs could impact bald eagles or their habitat.

Section 7 of the Endangered Species Act requires consultation between the agency instituting the action and the U.S. Department of the Interior, Fish and Wildlife Service to develop procedures to insure that the proposed action will not jeopardize the continued existence of the threatened or endangered species. This consultation can be either formal or informal. Many potential conflicts are resolved through informal consultation where both parties mutually agree on procedures needed to protect the species. If adequate provisions for the protection of the species cannot be mutually agreed upon, formal consultation is required. The Fish and Wildlife Service must then, within 90 days of the requested consultation, advise the federal agency instituting the action of the procedure it should follow to protect the species, or must follow, if survival of the species is in jeopardy. If these are still unacceptable to the agency, the Act outlines a formal appeal process that can be implemented by the agency.

State regulations also mandate special consideration be given to threatened or endangered species such as the bald eagle. In Washington, regulations adopted to implement the Forest Practices Act of 1974 (Washington Forest Practice Board 1982) classify operations affecting the habitat of a threatened or endangered species as a "Class IV – Special Forest Practice" that may require an environmental assessment as well as an approved forest practice permit. These permits are required on both state and private lands. Oregon forest practice rules (Oregon Department of Forestry 1980) also require that "special consideration" be given "toward preserving any . . . habitat of any wildlife . . . species classified by the Department of Fish and Wildlife as being rare or endangered."

In addition to these legislative mandates, an interagency Pacific States Bald Eagle Recovery Team, appointed by the Fish and Wildlife Service under the authority of the Endangered Species Act, is developing a recovery plan for bald eagles. The plan, when completed, will include detailed information concerning procedures needed to insure survival of the species.

The following management considerations briefly discuss some procedures that may be used in the protection of bald eagle habitat.

Nesting Habitat

All management efforts directed toward nesting habitat should strive to maintain the current nesting population and habitat suitable for an increase in nesting populations in the future. Unoccupied nest sites, where habitat is still suitable, may be reoccupied after several years of nonuse and could provide habitat for an expanding eagle population. Other areas which appear to contain all requirements for nesting, even though they have no evidence of present eagle activity, should be considered as potential habitat.

Three major nesting habitat management approaches are currently in use: buffer, territory, and nesting region zonations.

Buffer Zone

The buffer zone concept, developed in Minnesota (Mathisen 1968), has been advocated by the U.S. Department of the Interior, Fish and Wildlife Service and widely used by the USDA Forest Service. Briefly, nesting sites are divided into primary and secondary management zones to buffer potentially-disturbing activities (fig.11A). The primary zone is a concentric circle around the nest tree 330 feet in radius where it is recommended that all human activity, development, and logging, be restricted. If the nest site is active, a secondary or seasonal zone extending 660 feet from the nest tree is established where it is recommended that activity be restricted during the critical breeding season. Research has indicated that this zoning approach often is inadequate and does not fully protect nesting territories (Juenemann 1973). Consequently, modifications of the concept have been developed to create systems that better protect all needs of nesting pairs and their young (Mathisen et al. 1977). These systems are discussed below.

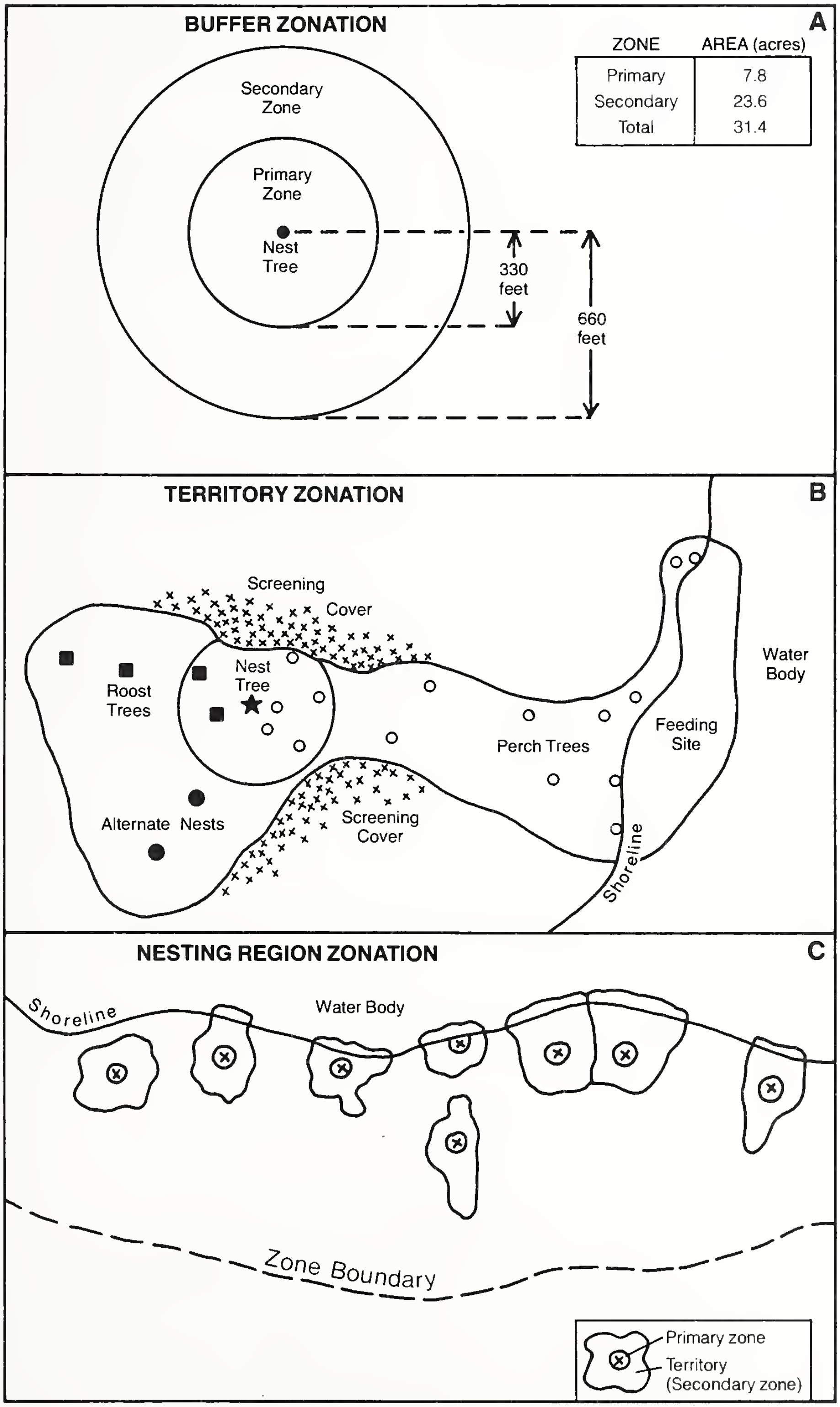


Figure 11.—Evolution of management concepts to protect nesting bald eagles. The buffer zone concept (A) has progressed to the territory zone concept (B) where all components of the nesting territory are protected by a zone extending beyond the primary buffer zone, while the nesting region zone plan (C) encompasses a large habitat area earmarked for protection and enhancement where multiple eagle nests exist.

Territory Zone

Guidelines utilizing this method have been developed for Oregon and Washington by the U.S. Department of the Interior, Fish and Wildlife Service (1981). The nesting territory is the area of concern in this management plan and the territory is delineated by observing the activity of the adults. This method continues to use the buffer zonation scheme but also attempts to contain within the zone frequently used perching and roosting sites as well as any alternate nest trees that occur within the territory. It provides protection to adjacent forest stands while at the same time taking into account variation in individual eagles' response to human activity (fig. 11B). Visual and topographic irregularities which may alter the zone distances are taken into account. Size and shape of both the primary and secondary zone may vary.

As with the buffer zone concept, a primary zone with a 330-foot radius is recommended to prevent disturbance to the nest, but this width should be determined on a site-specific basis. The secondary zone can vary from 660 feet to as much as one-half mile depending on the degree to which vegetation or topography screens the nest from potential disturbance. Fraser (1981) recommends a one-half mile zone when open regions are adjacent to the nest tree. Zones need not be circular but should reflect local physiographic conditions and the tolerance of the nesting pair to disturbance factors.

Temporal restrictions should be applied on a nest-by-nest basis since eagles have been observed on or near territories throughout the year (Fraser 1981). Temporal restrictions should be in effect year-long in the primary zone, but in Oregon and Washington, human activity in the secondary zone is restricted only during the period when birds are present, normally between January 1 and August 31 (fig. 12) (Anthony and Isaacs 1981, U.S. Department of the Interior, Fish and Wildlife Service 1981). While the likelihood that human activity will be disturbing is less after hatching and as young develop (Fyfe and Olendorff 1976), the best strategy is to keep activity to a minimum until the young have fledged and left the nesting area.

Stand elements in the nesting territory which require protection or enhancement include the nest tree, all trees containing alternate nests, snags and other trees used for perching and roosting, and vegetation which provides a buffer to reduce line-of-sight to disturbances. If vegetative buffers are present, restriction zones may be smaller and hence less land area is needed to protect the site. Timber stand improvements, such as thinning to promote rapid growth and to eliminate undesirable species, may be necessary within the territory in order to develop or maintain a multistructured characteristic of the stand with a desirable species composition.

Detailed management plans for individual nest sites are feasible and many have been prepared (Bill and Ransom 1980). If nest sites are located on private land, it may be possible, in exchange for tax breaks, to negotiate conservation easements which preclude land development and insure that the land owner will adhere to buffer zone guidelines. Land exchanges and other forms of title acquisition also may be used in protecting the nest site.

Nesting Region Zone

The nesting region zonation concept is a forest/wildlife cooperative management effort specifically designed for a large geographic area containing a number of active nests or potential nest sites. The primary goal of this concept is to insure the availability of habitat for existing and future populations (fig. 11C). Such a plan includes a combination of silvicultural methods designed to provide suitable nesting, perching, and roosting habitats, calls for the acquisition or negotiation of wildlife easements or cooperative management programs on private holdings; and limits the timber harvest to that commensurate with habitat management objectives.

This concept is being used in the Klamath Basin (Goold 1981) and the Fremont National Forest (Isaacs and Silovsky 1981) in Oregon. Specific objectives of the Klamath Basin management plan are: development of a multistoried, uneven-aged stand with 20 to 40 percent crown closure on 50 percent of the zone to insure that there will be sufficient area for nesting; thinning to maintain proper stocking levels and to enhance tree growth; selective harvest to develop a heterogeneous forest structure; and maintenance of 10 tall potential nest trees per acre. The plan recommends that these trees be at least 240 years old and have diameters of at least 38 inches. Restriction of human activity, especially during the sensitive nesting period, also is required. In an attempt to encourage nesting, efforts could be made to structure the tops of several dominant trees to accomodate a nest. U.S. Department of the Interior, Fish and Wildlife Service (1981) guidelines for enhancement of potential eagle nesting habitat provide additional information.

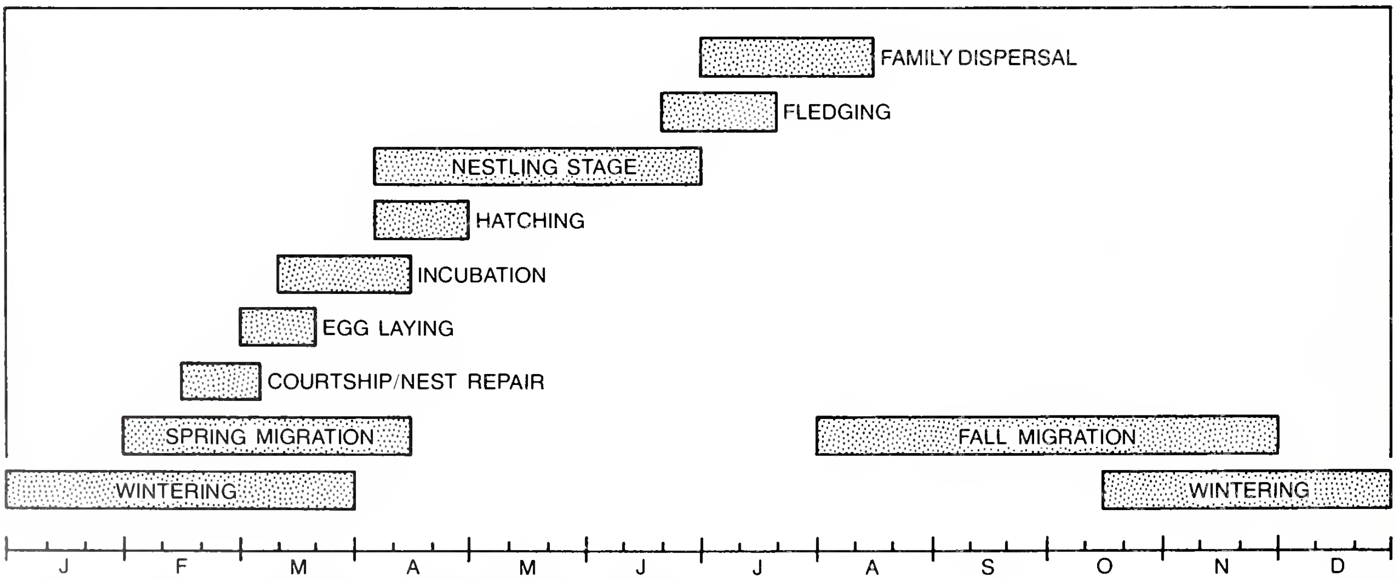


Figure 12.—Approximate year-round chronology of bald eagle activities, both breeding and nonbreeding, in Oregon and Washington (after Retfalvi 1965 and Isaacs et al. 1982).

Through silvicultural techniques, it may be possible to develop potential nesting habitat in second-growth stands. Until this has been conclusively demonstrated, however, there is an urgent need to maintain suitable old-growth forest habitats since eagles preferentially use them for both nesting and roosting (Anthony et al. 1982). Other species such as the spotted owl could also benefit from this protection (see chapter 12).

All forest land within one mile of the shoreline of major water bodies can be considered potential nesting habitat (U.S. Department of the Interior, Fish and Wildlife 1981). Primary management efforts should be directed at these stands. Protection, however, should not be limited to just these shorelines.

Because eagles establish large territories, stand manipulation for nest sites should be widely spaced to avoid territorial strife between nesting pairs. Clearcutting between nesting territories increases visibility and may increase territorial antagonism (Mahaffy 1981). This visibility also increases the potential for disturbance from human activity with the possible result being a need for wider buffer zones around the nest. Vegetative screening around the nest tree could eliminate most of these potential conflicts (Andrew and Mosher 1982). Unoccupied nests may be indicative of suitable habitat and protection of stands where they occur should be considered. Unattended nests could also indicate that human activity is preventing their use (Anthony and Isaacs 1981). Summer habitat use by subadults and nonbreeding adults needs to be studied to determine the habitat requirements of this segment of the population.

Wintering Habitat

Protective management strategies for wintering habitat, including both perching and roosting sites, are not unlike those recommended for nesting territories. Maintenance of habitat and restriction of human activity are the key elements of any plan to manage wintering bald eagles.

Perching

Since perching sites are closely associated with water, riparian habitat should be maintained and managed to provide suitable perch trees. Stalmaster and Newman (1979) suggest that vegetation containing large trees be maintained within a strip at least 165 feet wide along streams, lakes, and coastal shorelines where eagles are known to perch. Strips containing a variety of tree species, especially snags and tall deciduous trees, provide optimal perching habitat.

Leaving or planting strips of trees and understory vegetation has the added benefit of providing screening cover which can partially or completely shield eagles from disturbing human activity. Conifers and understory growth are particularly effective in screening activity. If the sight of disturbing activity is visually disrupted, even partially, its impact is mitigated. Stalmaster and Newman (1978) found that they could approach wintering eagles within 330 feet or less, 100 percent of the time if their presence was partially shielded by vegetation, but they could only approach 36 percent of the population within 330 feet if they were walking in the open. Based on these observations, they recommend establishment of screening zones of 250 to 330 feet in width of which at least 250 feet is comprised of thick vegetation. These vegetation zones not only serve to screen activities; they also can provide perching

and roosting trees, reduce erosion, and stabilize banks while minimizing the need for larger buffer zones (fig. 13A). When screening cover is not present and activity is in open view of eagles, buffer zones of inactivity would have to be extended to 800 to 1000 feet to be effective (Stalmaster and Newman 1978).

Roosting

Roosting areas, especially communal roost sites, should have a high priority for protection since they have several functions which aid winter survival. Buffer zones can be established around communal roosts using the same criteria as for perching sites (i.e. – at least 250 to 330 feet when screening cover is present, or 800 to 1000 feet in open areas). The U.S. Department of the Interior, Fish and Wildlife Service (1981) recommends a buffer zone of at least 1320 feet from the core zone of the roost area (fig. 13B). One roost in the Klamath Basin in Oregon is protected by a 3000 foot zone which probably is more than adequate to mitigate disturbance (U.S. Department of the Interior, Fish and Wildlife Service 1978b).

Timber cutting should not occur in roosting areas unless it will maintain or enhance the desired characteristics of the stand for eagles. Logging activities in stands adjacent to any roost should be designed to minimize disturbance during the wintering season (approximately November 1 to March 31). It should be recognized that cutting of adjacent stands could modify the protective

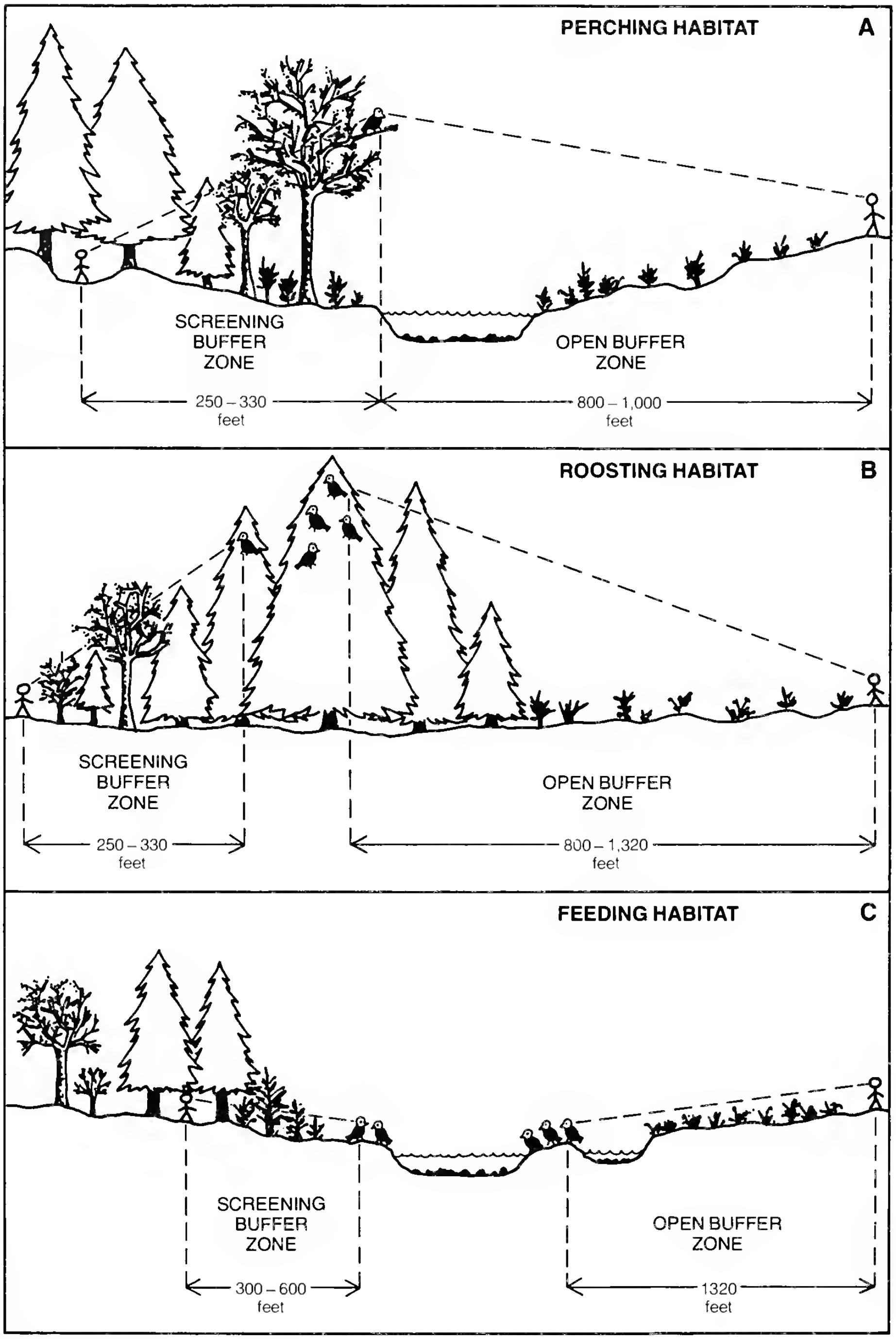


Figure 13.—Buffer zones should be established to protect winter perching (A), roosting (B), and feeding (C) sites of bald eagles. If thick vegetation, topographic, or other visual barriers are present, zone lengths can be shortened as shown for screening zones.

microclimate of the roost and might lead to its abandonment. Logging close to a roost also could increase the likelihood of windthrow.

Just as nesting habitat can be managed for potential use, roosting habitat can be managed and enhanced to insure the availability of suitable stands in the future. Old-growth stands close to winter feeding sites have the highest potential for use (Keister 1981). Again, uneven-age stand management and silvicultural manipulation similar to that recommended for nesting habitat can be employed to promote the development of preferred elements and to maintain desired stand characteristics. Maintenance of old-growth (200 to 400+ years old) forest may be an important objective (Anthony et al. 1982). Conifers with thick canopies provide a mild microclimate, but canopies should be discontinuous both vertically and horizontally. Old-growth deciduous trees in riparian situations may need to be maintained if use is observed. Desired characteristics include large trees extending above the canopy; open-structured, lateral branches high in the crown; and foliage above roost perches.

Feeding Habitat

Land management practices near aquatic environments can adversely affect bald eagle foraging habitat (Nature Conservancy 1976, Stalmaster 1980). Improper logging practices and road construction may result in increased erosion, sedimentation, and accumulation of aquatic debris, all of which could impact streams, wetlands, or estuaries (see chapters 4, 5, and 10) which provide potential prey species such as fish and waterfowl. Removal of streamside vegetation eliminates perching and roosting trees and can destabilize river banks, making them destructive to salmon spawning sites. Water levels and flow rates should be controlled where possible to reduce the loss of shoreline trees by erosion and flooding (U.S. Department of the Interior, Fish and Wildlife Service 1981).

In watersheds and coastal areas where eagles feed, use of toxic chemicals should be closely monitored to avoid contaminating prey. Poisoning of terrestrial prey sources also could adversely affect bald eagles. Persistent organochlorine pesticides and heavy metal pollutants can have serious impacts on eagle populations (U.S. Department of the Interior, Fish and Wildlife Service 1981). Their use should be restricted in areas where bald eagles are known to occur.

Because eagles standing on the ground at feeding sites are more sensitive to disturbance than those perching or roosting in trees (Knight 1981, Skagen 1980, Stalmaster and Newman 1978), the 800- to 1000-foot-wide buffer zones suggested for perching sites are not adequate. For feeding habitat, zones of greater lengths are recommended. A reasonable objective which would protect over 80 percent of all feeding eagles would be a buffer zone of at least 1320 feet (fig. 13C) (Knight 1981). Establishment of vegetation at feeding sites may not be beneficial since eagles require large, open regions for foraging, but vegetative screening on the margin of feeding areas would be advantageous. Management objectives should include provisions to allow eagles to feed without interference from human activity (Stalmaster 1981b). Human intrusion into feeding sites should be prohibited, especially early in the day, since feeding activity by wintering bald eagles is concentrated in the morning (Stalmaster 1980). Access for viewing eagles by interested citizens, especially from boats, should be restricted to minimize disturbance (Nature Conservancy 1976).

Bald eagles may be stressed by inadequate food supplies in winter (Sherrod et al. 1976; Stalmaster 1981a, 1981b), and activities associated with forest management practices have the potential for increasing this stress. Since eagle populations could be limited by food availability, food enhancement management is of paramount importance in any habitat management scheme. Excessive human activity at or around potential feeding sites may force eagles to winter in marginal habitat where food is less abundant (Stalmaster and Newman 1978). Disturbances which disrupt social activities of eagles can be detrimental to the overall foraging success of the population since eagles find and exploit food sources more efficiently while in groups. It should be emphasized that manipulative forest management for the purpose of improving eagle habitat could be largely futile if a sufficient food base to support the population is not maintained. If there is a limited prey base, wintering eagles may leave the area. Nesting birds, on the other hand, will likely remain but be less successful in their nesting attempts.

Conflicts between forest management activities and bald eagles have occurred in the past, and with the rapid removal of old-growth forests, eagle habitats may continue to be lost. Forest management and preservation of eagle habitat, however, are not entirely incompatible as long as the needs of eagles are recognized and provided for in long-range forestry programs. If nesting, wintering, and feeding habitats are adequately protected, and provisions made to insure that such habitats continue to be provided through future forest rotations, bald eagles will continue to inhabit the forests of Oregon and Washington.

References Cited

Allen, G. T. An analysis of bald eagle nest-site characteristics in Washington. 1981. Unpublished data. Olympia, WA: Washington Department of Game.

Anderson, R. J.; Bruce, A. M. A comparison of selected bald and golden eagle nests in western Washington. In: Knight, R. L. [and others] eds. Proceedings, Washington bald eagle symposium; 1980 June 14-15; Seattle, WA. Seattle, WA: The Nature Conservancy; 1980: 117-120.

Andrew, J. M.; Mosher, J. A. Bald eagle nest site selection and nesting habitat in Maryland. J. Wildl. Manage. 46: 383-390; 1982.

Anthony, R. G.; Isaacs, F. B. Characteristics of bald eagle nest sites in Oregon. 1981. Unpublished draft. Corvallis, OR: Oregon State University.

Anthony, R. G.; Knight, R. L.; Allen, G. T. [and others]. Habitat use by nesting and roosting bald eagles in the Pacific Northwest. 47th North Am. Wildl. and Nat. Resour. Conf. Trans.; Washington, DC: Wildlife Management Institute; 1982: 332-342.

Bill, P.; Ransom, T. Conservation easements for bald eagles in the San Juan Islands; survey and preparation of management plans. In: Knight, R. L. [and others] eds. Proceedings, Washington bald eagle symposium; 1980 June 14-15; Seattle, WA: Seattle, WA: The Nature Conservancy; 1980: 81-84.

Braun, C. E.; Hamerstrom, F.; Ray, T.; White, C. M. Conservation committee report on status of eagles. Wilson Bull, 87: 140-143; 1975.

Collopy, M. W. Food consumption and growth energetics of nestling golden eagles. Ann Arbor, MI: University of Michigan; 1980. 202 p. Dissertation.

Corr, P.O. Bald eagle (*Haliaeetus leucocephalus alascanus*) nesting related to forestry in southeastern Alaska. College, AK: University of Alaska; 1974. 144 p. Thesis.

Forbis, L. A.; Johnston [Holder], B.; Camarena, A. M.; McKinney, D. Bald eagle habitat management guidelines. San Francisco, CA: U.S. Department of Agriculture, Forest Service, California Region 5 Office; 1977. 60 p.

Franklin, J. F.; Dyrness, C. T. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1973. 417 p.

Fraser, J. The breeding biology and status of the bald eagle on the Chippewa National Forest. St. Paul, MN: University of Minnesota; 1981. 235 p. Dissertation.

Fyfe, R. W.; Olendorff, R. R. Minimizing the dangers of nesting studies to raptors and other sensitive species. Can. Wildl. Serv. Occa. Paper No. 23; 1976. 14 p.

Gerrard, J. M.; Gerrard, P. N.; Whitfield, D. W. A. Behavior in a non-breeding bald eagle. Can. Field-Nat. 94: 391-397; 1980.

Goold, J. W. Klamath bald eagle habitat management area. Klamath Falls, OR: U.S. Department of Agriculture, Forest Service, Winema National Forest, Klamath Ranger District; 1981. 99 p.

Grubb, T. G. A survey and analysis of bald eagle nesting in western Washington. Seattle, WA: University of Washington; 1976. 87 p. Thesis.

Grubb, T. G. An evaluation of bald eagle nesting in western Washington. In: Knight, R. L. [and others] eds. Proceedings, Washington bald eagle symposium; 1980 June 14-15; Seattle, WA. Seattle, WA: The Nature Conservancy; 1980: 87-103.

Hansen, A. J.; Bartelme, J. W. Winter ecology and management of bald eagles on the Skykomish River, Washington. In: Knight, R. L. [and others] eds. Proceedings, Washington bald eagle symposium; 1980 June 14-15; Seattle, WA. Seattle, WA: The Nature Conservancy; 1980: 133-144.

Hansen, A. J.; Stalmaster, M. V.; Newman, J. R. Habitat characteristics, function, and destruction of bald eagle communal roosts in western Washington. In: Knight R. L. [and others] eds. Proceedings, Washington bald eagle symposium: 1980 June 14-15; Seattle, WA. Seattle, WA: The Nature Conservancy; 1980: 221-229.

Hayes, S. R.; Gessaman, J. A. The combined effects of air temperature, wind and radiation on the resting metabolism of avian raptors. J. Therm. Biol. 5: 119-125; 1980.

Hunt, W. G.; Johnson, B. S. Impacts of a proposed Copper Creek Dam on bald eagles; second winter study. San Francisco, CA: Biosystems Analysis Report; 1981. 113 p.

Hunt, W. G.; Johnson, B. S.; Bulger, J. B.; Thelander, C. G. Impacts of a proposed Copper Creek Dam on bald eagles. San Francisco, CA: Biosystems Analysis Report; 1980. 143 p.

Isaacs, F. B.; Silovsky, G. Bald eagle management on the Fremont National Forest. Lakeview, OR: U.S. Department of Agriculture, Forest Service, Fremont National Forest, Supervisor's Office; 1981. 87 p. + appendix.

Isaacs, F. B.; Anthony, R. G.; Anderson, R. J. Distribution and productivity of nesting bald eagles in Oregon 1978-82. Murrelet. 64:33-38; 1983.

Juenemann, B. G. Habitat evaluation of selected bald eagle nests on the Chippewa National Forest. St. Paul, MN: University of Minnesota; 1973. 170 p. Thesis.

Keister, G. P., Jr. Characteristics of winter roosts and populations of bald eagles in the Klamath Basin. Corvallis, OR: Oregon State University; 1981. 82 p. Thesis.

Knight, R. L.; Athern, J. B.; Brueggeman, J. J.; Erickson, A. W. Observations of wintering bald and golden eagles on the Columbia River, Washington. Murrelet 60: 99-105; 1979.

Knight, R. L.; Friesz, R. C.; Allen, G. T.; Randolph, P. J. A summary of the mid-winter bald eagle survey in Washington, 1981. Olympia, WA: Washington Department of Game Report; 1981. 74 p.

Knight, S. K. Aspects of food finding and avoidance behavior of wintering bald eagles. Bellingham, WA: Western Washington University; 1981. 64 p. Thesis.

Lincer, J.; Clark, W. S.; LeFranc, M. N., Jr. Working bibliography of the bald eagle. Sci. and Tech. Series 2. Washington, DC: National Wildlife Federation; 1979. 219 p.

MaGahan, J. Quantified estimates of predation by a golden eagle population. J. Wildl. Manage. 31: 496-501; 1967.

Mahaffy, M. S. Territorial behavior of the bald eagle on the Chippewa National Forest. St. Paul, MN: University of Minnesota; 1981. 92 p. Thesis.

Mathisen, J. E. Effects of human disturbance on nesting of bald eagles. J. Wildl. Manage. 32: 1-6; 1968.

Mathisen, J. E.; Sorenson, D. J.; Frenzel, L. D.; Dunstan, T. C. A management strategy for bald eagles. 42d North Am. Wildl. and Nat. Resour. Conf. Trans; Washington, DC: Wildlife Management Institute; 1977: 86-92.

Nature Conservancy. Skagit eagles: a management program for the Skagit River Bald Eagle Natural Area. Portland, OR: The Nature Conservancy; 1976. 71 p.

Newton, I. Population ecology of raptors. Vermillion, SD: Buteo Books; 1979. 399 p.

Opp, R. R. Status of the bald eagle in Oregon – 1980. In: Knight R. L. [and others] eds. Proceedings, Washington bald eagle symposium; 1980 June 14-15; Seattle, WA. Seattle, WA: The Nature Conservancy; 1980: 35-41.

Oregon Department of Forestry. Field guide to Oregon Forest Practice rules. 7th revision. Salem, OR: Oregon Department of Forestry; 1980. 59 p.

Pramstaller, M. E. Nocturnal, preroosting, and postroosting behavior of breeding adult and young of the year bald eagles (*Haliaeetus leucocephalus alascanus*) on the Chippewa National Forest, Minnesota. St. Paul, MN: University of Minnesota; 1977. 97 p. Thesis.

Retfalvi, L. I. Breeding behavior and feeding habits of the bald eagle (*Haliaeetus leucocephalus* L.) on San Juan Island, Washington. Vancouver, BC: University of British Columbia; 1965. 180 p. Thesis.

Robards, F. C.; Hodges, J. I. Observations from 2,760 bald eagle nests in southeast Alaska. Juneau, AK: U.S. Department of the Interior, Fish and Wildlife Service Report; 1977. 27 p.

Russell, D. Occurrence and human disturbance sensitivity of wintering bald eagles on the Sauk and Suiattle rivers, Washington. In: Knight R. L. [and others] eds. Washington bald eagle symposium; 1980 June 14-15; Seattle, WA. Seattle, WA: The Nature Conservancy: 1980: 165-174.

Servheen, C. W. Ecology of the wintering bald eagles on the Skagit River, Washington. Seattle, WA: University of Washington; 1975. 96 p. Thesis.

Sherrod, S. K.; White, C. M.; Williamson, F. S. L. Biology of the bald eagle on Amchitka Island, Alaska. Living Bird 15: 143-182; 1976.

Skagen, S. K. Behavioral responses of wintering bald eagles to human activity on the Skagit River, Washington. In: Knight R. L. [and others] eds. Proceedings, Washington bald eagle symposium; 1980 June 14-15; Seattle, WA: Seattle, WA: The Nature Conservancy; 1980: 231-241.

Stalmaster, M. V. Winter ecology and effects of human activity on bald eagles in the Nooksack River valley, Washington. Bellingham, WA: Western Washington University; 1976. 100 p. Thesis.

Stalmaster, M. V. Management strategies for wintering bald eagles in the Pacific Northwest. In: Knight, R. L. [and others] eds. Proceedings, Washington bald eagle symposium; 1980 June 14-15; Seattle, WA. Seattle, WA: The Nature Conservancy; 1980: 49-67.

Stalmaster, M. V. Ecological energetics and foraging behavior of wintering bald eagles. Logan, UT: Utah State University; 1981a. 157 p. Dissertation.

Stalmaster, M. V. An energetics simulation model for managing wintering bald eagles in Washington. Olympia, WA: Washington Department of Game Report; 1981b. 123 p.

Stalmaster, M. V.; Gessaman, J. A. Food consumption and energy requirements of captive bald eagles, J. Wildl. Manage. 46: 646-654; 1982.

Stalmaster, M. V.; Newman, J. R. Behavioral responses of wintering bald eagles to human activity. J. Wildl. Manage. 42: 506-513; 1978.

Stalmaster, M. V.; Newman, J. R. Perch-site preferences of wintering bald eagles in northwest Washington. J. Wildl. Manage. 43: 221-224. 1979.

Stalmaster, M. V.; Newman, J. R.; Hansen, A. J. Population dynamics of wintering bald eagles on the Nooksack River, Washington. Northwest Sci. 53: 126-131; 1979.

Stewart, P. A. Weight changes and feeding behavior of a captive-reared bald eagle. Bird-Banding 41: 103-110; 1970.

Thelander, C. G. Bald eagle reproduction in California, 1972-73. Sacramento, CA: California Department of Fish and Game Report No. 73-5. 1973. 17 p.

U.S. Department of the Interior. Determination of certain bald eagle populations as endangered or threatened. Federal Register 43: 6230-6233; 1978.

U.S. Department of the Interior, Fish and Wildlife Service. The Endangered Species Act of 1973. Including amendments of 1976, 1977, and 1978. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service; 1978a. 43 p.

U.S. Department of the Interior, Fish and Wildlife Service. Acquisition of the Bear Valley National Wildlife Refuge, Klamath County, Oregon: Environmental Impact Assessment. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service Report; 1978b. 46 p.

U.S. Department of the Interior, Fish and Wildlife Service. Bald eagle management guidelines for Oregon and Washington. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service; 1981. 10 p.

Ward, P; Zahavi, A. The importance of certain assemblages of birds as "information centres" for food finding. Ibis. 115: 517-534; 1973.

Washington Forest Practice Board. Washington forest practice rules and regulations. Olympia, WA: Washington Forest Practice Board, Department of Natural Resources; 1982. 76 p. + appendices.

Wood, B. Winter ecology of bald eagles at Grand Coulee Dam, Washington. In: Knight, R. L. [and others] eds. Proceedings, Washington bald eagle symposium: 1980 June 14-15; Seattle, WA. Seattle, WA: The Nature Conservancy; 1980: 195-204.

14

Silvicultural Options

Fredrick C. Hall
Charles McComb
William Ruediger

Table of Contents

Introduction

When Europeans first came to the Pacific Northwest, they found magnificent stands of timber from the Cascade Crest westward to the Pacific Ocean. Old-growth forest often exceeded 200 feet in height with tree diameters of 3 to 5 feet or more. These stands achieved this stature and size because of the longevity of dominant species. For example, Douglas-fir trees commonly live 400 to 700 years and noble fir trees 250 to 400 years. Western hemlock or Pacific silver fir were often found under these tall, majestic dominants. Insects, disease, windthrow, and suppression, would periodically kill some of the trees creating snags and downed material, all of which are used by wildlife.

Insects and disease were not the only factors disrupting the forest. Fire — conflagration fire which killed entire stands of trees — occurred over intervals ranging from 200 to 1000 years (Hemstrom and Franklin, 1982). Often 50 to 100 years would pass before these burns became fully restocked with native conifers (Franklin et al. 1981). Large fire-killed trees would often stand for 60 to 120 years (fig. 1) (Lambert 1981). As snags fell, they would produce 80 to 120 tons per acre of downed material that decayed over 100 to 300 year period (Lambert 1981). One hundred fifty years after the fire, a stand would be characterized by dead and down material, a closed crown canopy of trees often exceeding 150 feet in height, and by new snags developing from trees killed by suppression, insects, and disease.

Wildlife, fish, and streams in the Pacific Northwest evolved with these systems of disturbance, stand growth, and change in stand structure and tree species. Some wildlife became adapted to fire-created openings, some to the edge between a fire area and adjacent unburned stand, and others to a variety of stand structures. A few could inhabit closed sapling-pole and small sawtimber stands, and others found optimum habitat in large sawtimber and old-growth stand conditions. Old growth harbored a large number of wildlife species because it persisted for 200 to 400 years or longer, occupied a significant amount of land area, and had high structural diversity.

Figure 1.—Snags visible in this forest were caused by a crown fire that occured 40 years ago. Nearly 20 percent of the dead trees are still standing; the remainder are dead and down material. The new forest is about 40 feet tall in the closed sapling-pole-sawtimber stand condition.

These natural stands have been, and will continue to be, harvested for wood products. Sustained production of wood usually involves treating these stands silviculturally to assure regeneration and growth of desired tree species. High yield management strives to optimize wood production by prescribing periodic silvicultural treatments to harvest trees which might die, and to foster growth of residual trees so they will reach maximum economic value in the shortest possible time. Since different wildlife species are adapted to different kinds of stand conditions, from openings to old growth, silvicultural treatments of stands will affect wildlife habitats in many ways.

A comprehensive coverage of sivicultural treatments is not made in this chapter. Instead, discussion will center on concepts and principles, using only one kind of plant community and one intensive timber management system as an illustration. A nearly infinite number of silvicultural opportunities exist considering the vast differences in plant communities, site productivity, current vegetation,existing fish and wildlife species, and management direction on the westside of the Cascade Range in Oregon and Washington.

What is Silviculture?

What then, is silviculture? Ford-Robertson (1971) defined it as follows: "Silviculture is the science and art of cultivating forest crops, more particularly the theory and practice of controlling the establishment, species composition, stand structure, and growth of forests." Thus silvicultural treatment creates different kinds of stand conditions and therefore different fish and wildlife habitat. For example, using even-aged management, a stand may be clearcut creating open conditions and a uniform young stand during succession. In addition, silviculturists can select the tree species desired to replace the stand, control spacing of trees which affects their growth, determine how long to grow the trees which determines their size in both height and diameter, and can influence the presence or absence of snags by prescribing salvage cutting or snag falling.

A particular silvicultural treatment may be advantageous or disadvantageous depending on the wildlife species. Clearcut patches within old-growth stands provide habitat for wildlife requiring grass-forb or shrub conditions for reproduction and feeding. Wildlife of old growth are displaced or eliminated from the clearcuts but species of open areas are encouraged, resulting in an overall increase in wildlife species richness for the entire area. Edges created by clearcut units in old growth are important to a number of wildlife species. Some birds, such as bluebirds, tree swallows, northern flicker, and the American kestrel, require nest holes in trees, yet prefer to feed in the open. Deer and elk prefer to feed in open areas, yet take cover in the forest. A discussion of this is found in chapter 11.

Silvicultural practices can be applied following either of two approaches: even-aged or uneven-aged management. Even-aged is defined as a forest or stand composed of trees having no or relatively small differences in age; generally within 10 to 20 years of the same age, but up to a 30 percent difference in age in rotations greater than 100 years (Ford-Robertson 1971). Uneven-aged is defined as a forest or stand composed of an intermingling of trees that differ markedly in their ages, generally at least 10 to 20 years difference, or greater than 30 percent difference in rotations longer than 100 years (Ford-Robertson 1971). Adding "management" to these terms means that silvicultural treatments are designed to attain or maintain the desired forest structure.

Even- and uneven-aged management methods both require silvicultural treatment to attain diameter and height growth desired for either forest products or wildlife habitat. With periodic entries into the stand, trees are usually harvested before they die and become snags or dead and down material. If snags are desired, silvicultural practices can be modified to maintain a certain percentage of selected low vigor trees because these are the trees most likely to die and become snags. The two systems influence wildlife habitat in greatly different ways. When wildlife habitat is to be enhanced, a combination of even-aged and uneven-aged management is probably desirable.

Even-Aged Management

In even-aged management, a stand is regenerated by clearcut, seed tree, or shelterwood methods in which the new stand starts at the same time and is composed of those tree species desired. A rotation age is established, such as 95 years, during which precommercial thinning may be applied to thin trees to the desired spacing. Commercial thinnings are conducted to harvest trees that probably would die, and to maintain stand density at a level that will permit the desired height and diameter growth of residual trees. Thus most trees in the stand are very close to the same size and age, resulting in very low structural diversity within the stand.

Rotation age affects the amount of land area in grass-forb, shrub or open sapling-pole conditions. For example, a 95 year rotation will have regeneration units in these conditions for 15 years or approximately 15 percent of the rotation, and therefore 15 percent of the land area. The result is spatial heterogeneity in type of wildlife habitat. An area will have tracts in grass-forb, shrub, open sapling-pole, and closed sapling-pole-sawtimber stand conditions which produces a landscape with a diversity of wildlife habitat. No old-growth habitat is produced.

Uneven-Aged Management

Uneven-aged management is quite different because the objective is to maintain a variety of tree ages and sizes within the stand. There is no "rotation age" for the stand because trees of all sizes and ages are harvested selectively or in small groups or patches, and there is no beginning or end to the stand because there are always trees of various sizes and ages present. Tree species composing the stand must be shade tolerant to effectively reproduce and grow under a canopy. The objective is to cultivate three or more ages of trees in the stand which results in structural diversity.

The result of uneven-aged management, however, is spatial homogeneity in type of wildlife habitat and hence low diversity. There are no grass-forb or shrub conditions; there are no open sapling-pole conditions; and there is only one kind of habitat, that being a multi-layered forest of different tree sizes. The value for wildlife is related to the "target-tree size" which determines the amount of time an individual tree will live. For a target-tree size of 20 inches diameter at breast height (d.b.h.), stocking level control is maintained by periodic harvest of all tree sizes until the largest trees reach 20 inches d.b.h. at perhaps 100 years. In this example, no old-growth structure would develop.

Silvicultural Variables

Regardless of the management system employed, the silviculturist must still consider five variables when developing a treatment to meet a given objective: (1) stand condition which dictates what kind of treatment might be applied; (2) size of area treated which depends on the area of the stand, management objectives, and kind of harvest equipment usable on the given topography; (3) scheduling of treatment which involves rotation age for even-aged management, and target-tree size for uneven-aged management; (4) arrangement of stands in time and space which is influenced by stand condition prior to treatment and rotation age in even-aged management; and (5) topography such

as steepness of slope, shape of slope, and length of slope or distance from roads which influences selection of harvest system equipment and road location.

Stand Condition

Given a set of management objectives, stand condition will dictate what kind of silvicultural treatments should be considered. Stand condition encompasses the complete vegetation resource manipulated by a silviculturist. It includes current vegetation such as tree species, diameter, height, density, and standing volume; insects and disease in the stand; growth potential of the area; ecological reactions of the vegetation to treatment; plant indicators which imply which tree species are best adapted to the area; and current wildlife habitat components such as cavity trees, amount of dead and down material, and standing snags. Commercial thinning, for example, is not possible in an area that was clearcut only 10 years ago. Yet precommercial thinning to a low tree density can maintain this 10-year-old-unit in the grass-forb, shrub, or open sapling-pole conditions 5 to 15 years longer.

Growth potential of the site will influence spacing of the trees. Reaction of the plant community to clearcutting will determine what kind of early successional vegetation (grass, forbs,and shrubs) will colonize the unit, how much it will produce, and how severely it will compete with tree regeneration. Ecological charateristics of the plant community will influence selection of tree species to plant. In closed sapling-pole-sawtimber stand conditions, if a certain level of snags is desired, a commercial thinning will have to specify that a certain percentage of standing snags should be retained and that selected trees of low vigor and a given diameter should not be harvested so they can become snags at some future time.

Size of Area

Size of area treated is influenced by a number of factors: (1) the number of acres in a stand condition, (2) wildlife habitat and other management objectives, and (3) effect topography has on road location and harvest systems. With even-aged management, size of the regeneration unit determines the tract size for the entire rotation and thus the amount of the area that will be in any particular stand condition at any given time. For example, studies with birds in eastern forests have shown that the number of different species using an individual tract increased up to a tract size of about 84 acres but declined for a tract size of 110 acres. If wildlife species richness is an objective, an 84-acre tract may be desirable. On the other hand, if the objective is to improve deer and elk habitat, this size regeneration tract would be much too large (chapter 11), or if the objective was to provide habitat for northern spotted owls, the tract would be much too small. It should be remembered that an 84-acre clearcut will eventually become 84 acres in the closed sapling-pole-sawtimber stand condition and 84 acres in the large sawtimber stand condition. Should land managers desire to create old growth, they would still have only an 84 acre tract, not nearly sufficient for the minimum 300 acre nesting site required by the northern spotted owl (details in chapter 12).

Scheduling of Treatments

Scheduling of treatments is influenced by rotation age in even-aged management and by target-tree size in uneven-aged management. A 95 year rotation requires scheduling a regeneration unit on 1 percent of the land area every year (or 10 percent every 10 years), resulting in 10 percent of the area in grass-forb and shrub conditions 10 years old or less. In uneven-aged management, the stand must be thinned periodically to encourage height and diameter growth of young trees. This requires harvesting some trees of each age class plus some target-tree size individuals.

At times, scheduling to enhance wildlife habitat will pose some difficult problems. One important consideration is how to improve habitat on large tracts occupied by a single age-class of timber. These tracts were often the result of extensive wildfire such as the Yacolt burn in Washington or the Tillamook burn in Oregon. If wildlife management objectives are to have 10 percent of the land area in clearcut units less than 10 years old, some regeneration units will have to be scheduled in stands younger than rotation age while other stands will have to be deferred until after rotation age for harvest and regeneration.

Arrangements of Stands

Arrangement of stands in time and space is influenced by the three preceding variables: stand condition, size of area, and treatment scheduling. Maintaining or increasing wildlife habitat adds a fourth criterion to arrangement of stands. Deer and elk habitat can be greatly enhanced by spacing forage producing regeneration units 1200 feet apart so adjacent stands can be used for hiding and thermal cover (see chapter 11). Edge habitat can be maximized by locating clearcut units adjacent to old growth. Allocation of uneven-aged management to critical habitats, such as riparian zones, can improve wildlife habitat. Location of water sources in relationship to the treatment areas is often a critical wildlife habitat element.

Topography

Topography influences both wildlife distribution and systems of timber harvest (fig.2). Slopes under 35 percent generally permit ground yarding and thus maximum flexibility in selecting size of area, scheduling of treatment, arrangement of stands, and selection of even or uneven-aged management. In contrast, slopes over 80 percent require cable, helicopter or balloon yarding systems which are influenced by length of slope, shape of slope, and distance from roads. Cable yarding systems can economically harvest large sawtimber and old-growth stands containing 75,000 board feet per acre over a distance of 2,000 feet from a road. Later commercial thinning in this stand, however, where only 5,000 to 7,000 board feet per acre are to be removed, probably could not be economically accomplished over the same 2,000 foot cable distance.

Uneven-aged management is difficult to apply on slopes to steep for ground yarding equipment. For example, yarding logs ranging from 6 to 20 inches in diameter over a stand 120 to 150 feet tall without significant damage to residual trees is a major engineering and economic problem.

Figure 2.—Topograghy influences both transportation systems and timber harvest methods. These in turn tend to determine the size and location of treatment units. Topograghy also influences wildlife distribution and use of habitat.

Topography, or topographic location of stands, can be important for wildlife habitat. The difference between north and south slopes influence thermal cover characteristics for deer and elk. Location of free water or riparian areas is often critical for some species such as the kingfisher and river otter. Thus, topography tends to influence arrangement of stands in time and space to enhance wildlife habitat.

Each of these silvicultural variables will be discussed in relation to featured species and diversity management.

Ninety-Five Year Rotation

A point of reference is needed to adequately consider these five silvicultural variables and to select even- or uneven-aged management to enhance wildlife habitat. The reference chosen is a 95 year rotation in temperate coniferous forest because a vast majority of timber management in western Oregon and Washington utilizes even-aged management. Ninety-five years was selected because 95 years is approximately the culmination of mean annual increment (MAI) for the site quality illustrated. Figure 3 depicts the rotation.

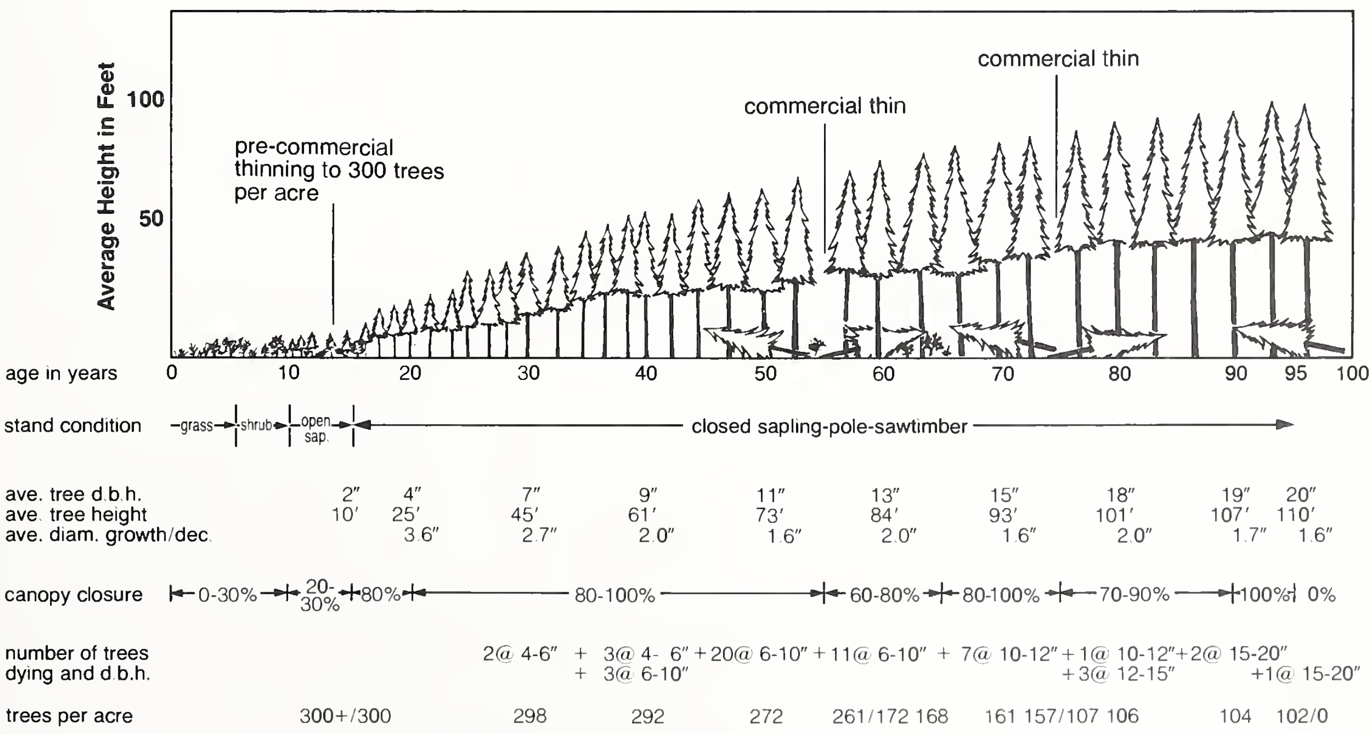


Figure 3.—A 95 year harvest rotation for Douglas-fir on DFSIM site index 90 (125) land showing silvicultural practices applied, growth rates, stand conditions that develop, and mortality rates that can be expected.

A site index of 90 at age 50 (SI 125, age 100) was chosen as the example for stand growth and mortality calculation using the stand growth simulation model DFSIM (Curtis et al. 1981). This is roughly an average site for National Forest land west of the crest of the Cascade Range. Privately-owned and Coast Ranges forest lands usually have a higher site index.

A clearcut unit is planted to 300 Douglas-fir trees per acre which is a 12 x 12 foot spacing. Grass-forb and shrub stand conditions last until about age 10 when trees became tall enough to qualify for the open sapling-pole stand condition. Since natural regeneration may occur, precommercial thinning is planned at age 12 to ensure stocking of only 300 trees per acre when they would be about 8 feet tall and 30 percent crown cover. By age 15, the trees should be about 14 feet tall with 60 percent crown cover, meaning the open sapling-pole condition changes to closed sapling-pole. "Open" wildlife habitat then, would have a duration of about 15 years.

First commercial thinning on this site index 90 land would occur at age 55 removing 30 percent of the basal area when the stand averages 12 inches d.b.h. The cut would harvest about 2,200 cubic feet and open the stand to about 80 percent crown cover. By this time, natural mortality should amount to 4 trees between 4 and 6 inches and 23 trees between 6 and 10 inches d.b.h. per acre resulting in about 320 cubic feet of deadwood. This eventually would create about 8 tons per acre of dead and down material. Some of the dying trees will be windfalls, the rest standing snags.

A second commercial thinning would occur at age 75 removing 22 percent of the basal area when the stand averaged 17 inches d.b.h. About 1800 cubic feet would be harvested opening the stand to about 80 percent crown cover. By this time, mortality should have amounted to a total of 4 trees between 4 and 6 inches, 34 trees between 6 and 10 inches, and 7 trees between 10 and 12 inches d.b.h. resulting in about 640 cubic feet of deadwood. This would eventually produce 16 tons per acre of dead and down material. Some of these trees, particularly mortality after thinning, will be windfalls.

Finally, the stand would be harvested and regenerated at age 95 when it averaged about 20 inches d.b.h. By now, accumulated mortality should be 4 trees 4 to 6 inches d.b.h., 34 trees 6 to 10 inches, 8 trees 10 to 12 inches, 3 trees 12 to 15 inches, and 3 trees between 15 and 20 inches d.b.h. resulting in about 920 cubic feet of deadwood or 23 tons per acre of future dead and down material. Up to 50 percent of the mortality could be windfalls. Final harvest would remove 9400 cubic feet of wood which, when added to the two commercial thinnings, should result in 13,000 cubic feet of wood for the rotation. Mortality would account for 7 percent of the total.

This rotation could probably be applied to 75 percent of the National Forest land in western Oregon and Washington. Topography, such as steep, long, broken or convex slopes, would probably preclude two commercial thinnings in a 95 year rotation on the rest of the forestland. On this 25 percent of the area, either one heavy commercial thinning or a one-cut clearcut system might be employed. A different rotation and commercial thinning regime would probably be applied to privately-owned land and forests of the Coast Ranges.

A rotation such as this has obvious effects on wildlife habitat. For example, 15 percent of the land area would be in grass-forb, shrub, and open sapling-pole stand conditions which are optimum forage areas for deer and elk and required habitat for wildlife species using open conditions for both reproduction and feeding. After crown closure exceeds 60 percent, roughly by age 15, the closed sapling-pole-sawtimber stand condition would prevail for the rest of the rotation. This stand condition provides poor wildlife habitat for most species.

Between age 15 and 55, before the first commercial thinning, 25 to 30 trees from 4 to 10 inches d.b.h. die from suppression, insects, disease, top breakage or blowdown creating habitat for those species that require down woody material.

Commercial thinning at age 55, which removes approximately 30 percent of the basal area, might create some forage areas for deer and elk. If snags are retained, they would enhance wildlife habitat for the next 20 to 40 years. Between the second commercial thinning at age 75 and regeneration at age 95, mortality should amount to 15 trees greater than 10 inches d.b.h. Of these, 9 would be 10 to 12 inches, 3 would be 12 to 15 inches, and 3 would be 15 to 20 inches in diameter. DFSIM does not specify cause of mortality but Curtis (personnel communication) indicates that at least one-half of the mortality factors such as suppression or disease results in a standing dead tree.

Using the assumption that at least one-half of the mortality results in a standing dead tree or snag, the percentage of cavity excavator requirements that are being met can be calculated (see table 9, chapter 7). In the temperate coniferous forest plant community, on which this example is based, five woodpecker species are commonly found. They are downy woodpecker, hairy woodpecker, red-breasted sapsucker, northern flicker, and pileated woodpecker. During the last 20 years of the 95 year rotation, approximately 20 percent of the land area, snag densities would accomodate 100 percent of the maximum downy woodpecker populations and 60 percent of maximum populations of hairy woodpeckers, red-breasted sapsuckers and northern flickers. None of the snag requirements of pileated woodpeckers would be met, because tree diameters at final harvest have not reached the sizes preferred by this woodpecker. Thus, during the last 20 years of the rotation, about 65 percent of woodpecker habitat requirements would be met.

Prior to 75 years into the rotation very few of the snag requirements of most woodpecker species would be met because of small tree diameters. To accommodate cavity users during the early stages of a rotation, snags must be carried over from the period prior to harvest. Snags need not be removed with regeneration cutting. In fact, retaining the maximum number of snags per acre following yarding will greatly enhance wildlife habitat well into the next rotation, particularly for those snags exceeding 15 inches d.b.h. Chapter 7 discusses yarding systems that will permit retention of maximum snags per acre.

Silviculture and Wildlife Habitat

Another wildlife consideration, particularly in regard to regeneration harvest, is maintenance or enhancement of dead and down material which is utilized to some degree by approximately 150 wildlife species (chapter 8). Natural mortality in this 95 year rotation should produce about 23 tons per acre of dead and down material. Yarding systems and site preparation which protect some of this material, particularly the larger diameter logs, might be considered. Broadcast burning to reduce slash and small diameter logs will enhance access by deer, elk, and tree planters while retaining larger diameter material. Yarding unmerchantable material discourages accumulation of dead and down woody wildlife habitat.

The 95 year rotation for an average National Forest site in the example just discussed, is a starting point for evaluating impacts of silvicultural treatment on wildlife habitat and, more importantly, as a basis for modifying silvicultural treatment to enhance wildlife habitat when that is a land management objective. There is little question that public land managers must balance objectives between maintaining and enhancing wildlife habitat and a steady flow of wood products. To help accomplish this balance, the land manager has three options for dealing with wildlife habitat: (1) management for featured species habitat, (2) management for habitat diversity to ennance species richness, and (3) a combination or a balance between featured species and diversity objectives. The following sections will deal with these options.

Featured Species Management

Featured species are those wildlife whose habitat requirements will be given special attention because they are threatened or endangered species, have been named a sensitive species by a state, or are to be given emphasis according to management direction. The species discussed here have already been given selective emphasis in this book: salmonids (chapter 10), deer and elk (chapter 11), northern spotted owl (chapter 12), and bald eagles (chapter 13). Habitat requirements for each will be summarized, then discussed in regard to even-or uneven-aged management and the five silvicultural variables from the previous example.

Salmonid Habitat[1/]

Salmonids (salmon and trout), both resident and anadromous species, are widely distributed in streams, lakes, ponds, and estuaries throughout western Oregon and Washington. Salmonids require cool, clear, relatively sediment-free water for spawning and rearing. Large woody debris is important in establishing and maintaining a diversity of habitats in stream channels. Free access for fish movement both up and downstream must be maintained to fully utilize available habitat. Sedimentation resulting from road construction and timber harvesting activities can severely impact spawning and rearing areas, while removal of vegetation along stream courses may permit water temperatures to exceed optimum levels and also removes a source of nutrients to the stream in the form of litterfall.

Vegetative stand conditions are important to salmonids primarily from the standpoints of how stream temperatures are affected, nutrient flows are altered, and the source of large woody debris to stream channels is changed. Grass-forb and shrub stand conditions provide little or no shading for streams and few nutrients in the form of litterfall. Although deciduous trees in riparian zones can often provide shading and a continued nutrient flow, removal of all mature or old-growth coniferous trees from these zones eliminates the source of large woody debris that is important in the maintenance of stream diversity.

Size of area is directly proportional to the length of stream channel that is impacted by forest management activities. Small dispersed harvest units in a stream drainage may actually benefit salmonid production because increased light penetration in restricted areas tends to increase food production in the stream. Where large portions of a drainage basin are impacted at one time, the cumulative effects of temperature and sedimentation on salmonid habitat can be severe with losses occurring downstream, in many cases as far as the estuaries. With even-aged management, rotation length becomes an important factor. With shorter rotations greater portions of a stream course will be impacted at one time. For example, with a 60 year rotation 25 percent of the land area will be in open stand conditions whereas only 15 percent of the land area will be in open condition with the 95 year rotation and 10 percent of the area in open condition with a 130 year rotation.

Scheduling of treatment could involve either even- or uneven-aged management. Uneven-aged management would best protect the integrity of the riparian zone along the stream course, would provide the needed shading and source of nutrients, and if a large target tree diameter was selected, would maintain a source of woody debris for the stream

[1/] All habitat and behavioral characteristics for salmonids used in this section were taken from chapter 10.

channel. Even-aged management, if applied in dispersed cutting units should maintain water quality, but special provisions would be required if a source of large woody debris is to be maintained.

Arrangement of stands in time and space is important, particularly if an even-aged management system is applied. To avoid cumulative effects on water temperatures and sedimentation, cutting units should be dispersed throughout a drainage basin and where streamside vegetation is removed, adjacent cutting units should not be harvested until vegetation on the original unit reaches the stage where it can provide adequate shade for the stream.

Topography influences site selection for roads and type of harvesting equipment used. Roads should be constructed on benches or ridgetops away from riparian zones. On gentle slopes wheeled or tracked skidding equipment can be used. On steeper slopes cable systems are required. Cable systems should be laid out to skid logs away from streams unless the system will permit logs to be "flown" over the stream without damage to the stream or its adjacent vegetation.

Deer and Elk Habitat[2/]

Deer and elk have an affinity for edge habitat. They prefer to forage in a clearcut or natural burn, yet require hiding and thermal cover in adjacent forests. Heaviest use by deer and elk occurs within 600 feet of the forest edge, both within openings and within the forest stand. Hiding cover is a vegetative condition dense enough to hide 90 percent of an elk or deer 200 feet or less from an observer. Thermal cover is a timber stand over 40 feet tall and greater than 70 percent crown cover. In addition, under adverse weather conditions, deer and elk have need for optimal cover. This consists of a two-storied stand with overstory trees over 21 inches d.b.h. with 70 percent or greater combined crown cover of overstory and understory trees. This means 40 to 60 percent or greater cover of overstory trees and 10 to 30 percent cover of understory trees which permits reasonable productivity of shrubs or herbs on the forest floor for maintenance forage.

Best deer and elk habitat is composed of a mix of four stand conditions: open forage areas, hiding cover, thermal cover, and where weather conditions can be severe, optimal cover. Primary forage areas, clearcuts, require even-aged management to provide openings and edge effect where animals can move quickly into hiding or thermal cover. Clearcut units can be enhanced for deer and elk habitat if precommercial thinning occurs early to maintain less than 60 percent tree crown cover for a maximum length of time. In addition, the unit can be seeded with palatable grasses and forbs and fertilized to enhance forage production (chapter 11).

Hiding cover develops naturally following regeneration as shrubs and trees grow taller than elk or deer. As stands grow, they approach the minimum requirement of thermal cover at about age 30. From this point on, they continue to furnish thermal cover until commercially thinned at age 55. Heavy thinning at this age, removal of 50 percent of the basal area instead of 30 percent, should open the stand to 60 percent crown cover and enhance forage production for deer and elk. A similar treatment might be applied at the 75 year commercial thinning.

Optimal deer and elk cover, a two-storied forest stand with overstory trees of 21 inches d.b.h. or greater with shrubs and herbs, requires a rotation longer than 95 years and stand conditions similar to uneven-aged management. This can be attained by extending the 95 year rotation with a heavy commercial thinning at age 95 instead of a regeneration cut. After thinning, establishment of an understory could be assured by planting 50 to 100 shade tolerant trees per acre. This planting would provide the tree understory needed to meet both thermal and optimal cover requirements of deer and elk.

Size of area is important. Ninety-five percent of deer and elk use in a clearcut unit occurs within 600 feet of the forest edge. Thus a circular unit can be no more than 1200 feet in diameter, or about 26 acres, for maximum utilization. More acreage can be attained with rectangular regeneration units. A clearcut 1200 feet wide and 3000 feet long contains 84 acres and would still be fully utilized by deer and elk. Consider again that size of the clearcut unit will dictate the size of the following stands as the trees grow and mature. Twenty-six acre blocks of thermal cover or optimal cover may not be large enough for some wildlife species.

Scheduling of silvicultural treatment greatly influences forage areas for deer and elk. The 95 year rotation example will have 15 percent of the land area in grass-forb, shrub and open sapling-pole conditions if precommercial thinning to 300 trees per acre is included in the treatment. If 15 percent of the land area in forage is below the desired level for deer and elk habitat, the amount could be increased with a shorter rotation. A 55 year rotation would have 27 percent of the land area in forage areas. Mixing rotation lengths and heavier commercial thinning would be options for increasing forage.

Arrangement of stands is important in optimizing deer and elk habitat. Best habitat conditions are attained where a clearcut is placed adjacent to an area that provides thermal cover or optimal cover. Thus units must be distributed on the landscape in a way that maximizes contrast at the edge. A clearcut unit placed adjacent to other units providing only hiding cover, does not optimize deer and elk habitat because they need thermal cover during both winter and summer. Arrangement of forage and cover units must also consider behavior of the animals. Generally, a herd of deer and elk will use a drainage of 1,000 to 6,000 acres. Clearcut units, which later develop into hiding and thermal cover stand conditions, should be distributed within the drainage in a manner to optimize forage-cover ratios, provide cover near or adjacent to water sources, and provide cover along travel routes.

Topography plays an important part in deer and elk habitat. Readily available water in a drainage system is optimum. In the Coast Ranges winter and summer deer and elk range tends to be the same, whereas in the Cascade and Olympic Mountains, the animals winter at lower elevations in the temperate coniferous forest and summer at higher elevations in the high temperate coniferous forest and subalpine forest parks. Steep topography greatly influences timber harvesting systems,

[2/] All habitat and behavioral characteristics for deer and elk used in this section were taken from chapter 11.

shape and size of harvest units, and distance between roads. Deer and elk generally prefer to use slopes less than 50 percent, and tend to stay away from areas near roads that are continuously traveled. Optimizing deer and elk use of habitat often involves closing roads to provide areas of 200-400 acres where the animals can forage, rest, or raise young without being disturbed by human activity.

Northern Spotted Owl Habitat[3]
Optimum habitat for the northern spotted owl is an old, multi-storied (uneven-aged) forest stand of 65 to 80 percent combined crown cover, commonly referred to as old growth. Nesting owls have been found in stands 230 to 600 years old with structural damage and decay. Sixty-four percent of northern spotted owl nests have been found in natural cavities (even the pileated woodpecker does not excavate a hole large enough for this owl). Most of these natural cavities are in living trees with the broken top of an old-growth tree a favored site. Cavity trees require a large d.b.h. because of the large diameter required at the nest site to accommodate a bird 18 to 22 inches tall. Most of the remainder, 27 percent of the nests, have been found in branch platforms or mistletoe clumps. The recommended area of old growth around the site is at least 300 acres, with an additional minimum of 700 acres of old growth within a 1.5 mile radius for foraging. Foraging areas for most owls range from 2270 acres to 3460 acres. A major food item of northern spotted owls is the flying squirrel, a secondary cavity nester. Habitat for the northern spotted owl is also suitable for pileated woodpeckers and other old-growth associated species.

In Oregon and Washington west of the Cascade Range, northern spotted owl nesting has been almost exclusively in natural stands. Prudence suggests retaining these stands, without salvage, until silvicultural treatment has proved capable of creating suitable habitat. Theoretically, a silvicultural system could be devised to attain optimum nesting habitat. For example, stand conditions suggest uneven-aged management which could be initiated with the 95 year rotation of site index 90. Starting at age 95, instead of regeneration harvesting, commercially thin and assure establishment of understory trees. Since Douglas-fir has a long life expectancy, the overstory could probably be retained for another 300 years with a target tree size of perhaps 40 inches d.b.h. On better sites, such as the Coast Range, 60 to 80 inches is possible. Optimum habitat, however, is only 30 to 45 percent understory crown cover. Fifty to 100 years after the last commercial thinning, understory crown cover could become excessive and reduce the stand's effectiveness as spotted owl habitat. Stocking level control, utilizing precommercial and commercial thinning of the understory trees could enhance northern spotted owl habitat conditions and produce some forest products. Salvage of overstory trees and down logs should be prevented to assure habitat for northern spotted owl prey.

For the northern spotted owl, number of acres in optimum stand conditions is critical. If habitat is to be created, stands must exceed 300 acres. Owls forage primarily in mature and old-growth forest stands avoiding clearcuts and young second-growth stands. Foraging areas used by individual birds varied from 2270 to 3460 acres. For optimum conditions it appears this acreage should be in not more than two or three stands, with the minimum size being 300 acres.

Scheduling requires a long-term, uneven-aged, "old-growth" system. Minimum spotted owl habitat requirements might be attained at age 200 with the treatments discussed above. Habitat should become more effective following age 200 as the stand continues to age.

Chapter 12 suggests that arrangement of stands should consider a maximum radius of 1.5 miles flight distance from the nest site for distribution of spotted owl habitat. In addition, to maintain viable populations and breeding pairs, nest sites should not be closer than 3 miles, nor more than 12 miles apart. A spring or stream providing free water year-round within the nest grove is desirable. If the current target of 400 nesting pairs of northern spotted owls is to be maintained in the state of Oregon, designation and retention of current nest and feeding areas are important. This will be a significant factor in determining the size and arrangement of stand conditions necessary for future habitat.

Topographic considerations for the northern spotted owl are of little importance if adequate areas of older forest stands are present. Steepness or length of slope apparently do not influence the birds' nesting or foraging behavior.

Bald Eagle Habitat[4]
In western Oregon and Washington the presence of a large body of water or river to provide a food source for bald eagles seems essential. Bald eagles have three kinds of behavior which influence their selection of habitat: nesting in tall, preferably live coniferous overstory; perching on snags, dead-topped trees, or deciduous trees to watch for food; and roosting to obtain winter thermal protection. In general, they prefer a multi-storied stand where they use the overstory for nesting and perching. Bald eagles seem to prefer trees greater than 115 feet tall that are 120 to 150 percent taller than the subcanopy trees. Most nesting and perching sites are within 400 feet of large bodies of water. Fifty percent of the eagle activity for nesting and perching is within 150 feet of water. For nest sites, they prefer pure conifer stands in which either Douglas-fir or Sitka spruce are dominant, the trees are past active height growth, and the total stand ranges from 10 to 70 percent combined crown cover of overstory and understory trees. Optimum conditions are 10 tall trees per acre, creating an open overstory of 5 to 20 percent crown cover that provides the birds with easy flight access to the trees. Most bald eagle nests have been found in stands that have been subject to some logging activity. Optimum perching habitat at feeding sites must be adjacent or close to water and should include trees with large branches. Perch trees can be either conifer or hardwood, but hardwoods are preferred. For roosting habitat, the primary consideration is winter protection such as leeward topography or bottomland location, and

[3] Habitat and behavioral characteristics of northern spotted owls used in this section were taken from chapter 12.

[4] All behavioral and habitat characteristics of bald eagles used in this section were taken from chapter 13.

optimally within 0.3 to 0.6 miles but may be several miles from water. Finally, they require a minimum of human disturbance, particularly in regard to visual contact with people.

Preferred nest site stand conditions include an open multi-storied structure with Douglas-fir or Sitka spruce overstory trees dominant. In an intensively managed forest, to develop an open, tall overstory requires commercial thinning to promote height and diameter growth with heavy enough thinning to provide a low final density. For example, the 95 year rotation could be thinned to 40 trees per acre, a shelterwood condition. Following thinning, assure establishment of an understory by natural or artificial means. The understory should be maintained at a 50 to 70 percent crown cover to permit screening of human interference and yet permit some observation of the ground by eagles.

Size of area is important and quite different from requirements for the northern spotted owl. Using the buffer zone concept, the nest site should have a minimum 330 foot radius with no human activity, about 8 acres around the nest tree. In addition, activity during the critical breeding season should be restricted within a 660 foot radius of the nest tree (31 acres total), and understory screening maintained. A more recent concept called territory zonation attempts to encompass within the protective zone all the major activities of a pair of eagles, including roost trees, perch trees, feeding areas, and alternate nest sites. Size of the protective zone will vary with topographic features and the activity patterns of the birds. Where a number of nest sites are located in an area the nesting region zonation concept may be applied and silvicultural methods applied to a broad area to insure nesting, perching, and roosting habitats are maintained for present and future eagle populations. Roosting areas require about a ¼ mile buffer zone away from human activity.

Scheduling of treatment is influenced by selection of even- or uneven-aged management and rotation length. For example, on site index 90 land, rotations must exceed 100 years for the overstory to attain heights greater than 115 feet. On better sites, such as in the Coast Ranges, this height may be attained in 50 years. Optimum bald eagle nesting habitat seems to be about 240 years at 38 inches d.b.h. for overstory trees. The understory, however, may need to be managed to maintain it well below the canopy of overstory trees and at less than 70 percent crown cover. Partial cutting in the understory and some regeneration over a 100 to 200 year period seems desirable. Understory treatment should be scheduled during autumn and early winter to minimize disturbance. "Rotation age" of the overstory should be determined by longevity and density of the trees.

Arrangement of stands, of course, is dictated by the foraging habits of bald eagles. Nesting and perching sites must be located adjacent to large bodies of water or good fish producing streams. Due to territory size, these perching and nesting sites should be 2 to 2.5 miles apart.

Topographic considerations require nearby large bodies of water for feeding sites, and protective topography during winter roosting.

Portions of all the featured species' habitats discussed above have one kind of stand condition in common: an old, multi-storied stand with snags and broken or dying trees; a stand structure which is commonly referred to as old growth.

Old-Growth Considerations

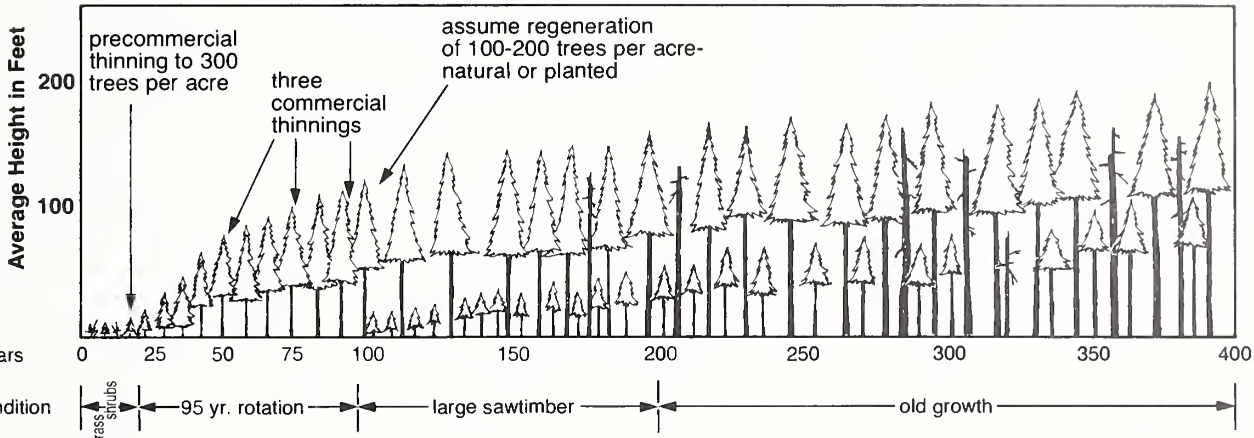
For the purposes of this discussion, Heinrichs' (1983) definition of old growth will be used. An old-growth forest stand contains: (1) two or more tree species in a wide range of sizes and ages; often a long lived seral dominant, such as Douglas-fir, is associated with shade tolerant species such as western hemlock; (2) deep, multi-storied crown canopy; (3) more than 10 trees per acre at least 200 years old; (4) more than 10 snags over 20 feet tall, and more than 20 tons of down logs per acre; and (5) at least four large snags and an equal number of logs 25 inches in diameter and 50 feet long per acre.

Old-growth stands have not been produced by silviculture treatment. Many concepts and principles of silviculture, however, suggest creating conditions mimicking old growth is feasible. Silvicultural treatment to attain these stand conditions will be described using the temperate coniferous forest with an overstory of Douglas-fir and an understory of western hemlock as an example. When overstory trees are reduced to 10 trees per acre and are less than 30 percent Douglas-fir, stand conditions are no longer considered to meet the definition of "old growth".

Growth and development beyond age 100 was estimated using some of the USDA Forest Service's ecology program intensive sample plots, silvicultural expertise and wildlife biologist's estimates, as well as information contained in Franklin et al.'s (1981) publication on ecological characteristics of old-growth Douglas-fir forests.

Douglas-fir is usually a pioneer or seral species requiring natural fire, clearcut, or shelterwood conditions for regeneration. Application of uneven-aged management will eventually eliminate Douglas-fir because it cannot adequately reproduce in the shade of a multi-storied stand. For this reason the same treatment is applied to the stand as would be applied for the 95 year rotation of site index 90 (fig. 4) but instead of regenerating the stand, a third commercial thinning is applied at age 95 leaving 80 trees per acre. By age 100, the average stand height should be 118 feet, the average diameter growth approximately 2 inches per decade, and the average stand diameter 22 inches d.b.h., large sawtimber stand condition. Treatment should favor Douglas-fir in the overstory and should leave a number of rotted, defective trees. Establishment of tree understory should be assured by either natural or artificial means to obtain 100 to 200 western hemlock seedlings per acre. If additional silvicultural entries are to be made in the stand, overstory salvage should be avoided in order to retain the maximum number and size of large snags. Control of tree understory density may be desirable to optimize wildlife habitat.

Leaving 80 trees per acre, a moderately low stand density, is designed to increase diameter growth of leave trees. By age 150, however, stand basal area should increase to the point where diameter growth has slowed to about 1 inch per decade. This high stand density tends to encourage death of



	25	50	75	100	150	200	250	300	350	400
ave. tree d.b.h.	6"	11"	16"	22"	29"	32"	35"	37"	39"	40"
ave. tree height	35'	73'	96'	118'	133'	145'	155'	165'	174'	183'
ave. diam. growth/dec.	3.0"	1.6"	1.6"	2.0"	1.0"	0.6"	0.5"	0.4"	0.4"	0.3"

number of trees dying and d.b.h.
4@ 4- 6" + 11@ 6-10" + 4@ 15-20" + 15@ 22-25" + 14@ 25-27" + 10@ 27-29" + 8@ 29-31" + 7@ 31-32"
23@ 6-10" 8@ 10-12" 5@ 20-22"
3@ 12-15"
3@ 15-20"

overstory trees per acre	300	273	80	71	56	42	32	24	17

Figure 4.—A 400 year old-growth rotation for Douglas-fir on DFSIM site index 90 (125) land showing conditions that develop, and mortality rates that can be expected.

intermediate and suppressed trees in the original overstory and reduce height growth of understory trees. By age 200, average stand diameter should be about 32 inches d.b.h., average stand height 145 feet, and average diameter growth 0.6 inches per decade. The understory, after 100 years of retarded growth under a canopy, would probably be 50 to 60 feet tall. Mortality should amount to 4 trees 15 to 20 inches d.b.h., and another 20 trees between 20 and 25 inches d.b.h., for a total of 24 trees greater than 15 inches d.b.h. per acre. There would be about 56 dominant trees per acre at this time. Trees dying prior to age 100 should have fallen to the ground creating about 23 tons of dead and down material. Windfalls between age 100 and 200 would add to this material. This stand condition meets the definition of old growth.

From this point the stand could probably persist for at least another 200 years, becoming better old-growth habitat with age. Beyond age 400, the stand might no longer meet old-growth requirements for tall, seral trees. At age 400, there should be approximately 17 trees per acre remaining in the overstory growing at only 0.3 inches diameter per decade with an average height of 185 feet and an average d.b.h. of 40 inches. Between age 200 and 400, approximately 40 trees should have died between 22 and 32 inches d.b.h. some of which would be windfalls. Snags produced prior to age 200 would probably have fallen to the ground producing at least 50 tons per acre of dead and down material.

Stand conditions between ages 200 and 400 meet the criterion of deer and elk optimal cover and northern spotted owl nesting and foraging habitat. Eagle habitat criteria are met between 300 and 400 years where overstory trees number less than 30 per acre. Optimum bald eagle habitat could be attained by age 200 if the third commercial thinning at age 95 left 40 trees per acre instead of 80. With low density such as this, diameter growth would initially be rapid and mortality would be reduced. Along stream courses this stand condition would provide the large woody debris needed to maintain stream habitat diversity.

Figure 4 demonstrates that old-growth conditions from age 200 to 400 would provide 100 percent of the snag requirements for all cavity dependent wildlife according to chapter 7. Ninety-five percent of the cavity dependent wildlife would be provided for between ages 100 and 200, the limitation being snag size which is only approaching 20 inches d.b.h. As discussed previously, the 95 year rotation would provide about 65 percent of the snag requirements between ages 75 and 95. As a result, a forest stand managed on a 400 year old-growth rotation should provide about 78 percent of the maximum number of snags for cavity dependent wildlife.

On the other hand, this 400 year rotation will provide only 3 to 4 percent of the land in open areas which are part of optimum habitat for deer and elk, and which are required for reproduction and feeding by a significant percentage of the wildlife species in western Oregon and Washington. Clearly, an old-growth rotation applied to all lands within a management unit will not optimize habitat for all wildlife. It provides habitat primarily for those species requiring or using large sawtimber and old-growth stand conditions. It does not maximize species richness or diversity.

Management For Diversity

The goal of management for habitat diversity, and enhancing species richness, requires maintaining habitat for at least viable populations of native and desired species. Maintaining viable populations is different from optimizing or maximizing populations of featured species. Silvicultural practices must be modified to create a broad spectrum of wildlife habitat from clearcut regeneration units to 400 year old growth. One way to evaluate management for diversity is to: (1) classify stand conditions for wildlife habitat, and (2) classify wildlife responses to these various habitats (appendices). Diversity, and thus species richness, is influenced most greatly by the grass-forb and shrub conditions with their attendant edges, and old-growth stand structure.

Silvicultural Considerations

Silvicultural treatments designed to enhance wildlife habitat diversity should have an objective of maintaining a number of stands in all essential wildlife habitat conditions of suitable sizes, optimally distributed over the landscape. To do this, two approaches can be used: even- and uneven-aged management. Uneven-aged management strives for several tree layers in the stand which results in maximum diversity of within stand structure but minimum between stand diversity. The variety of wildlife habitat is reduced because there is no land area in regeneration cuts and few edges. Even-aged management strives for a stand of one size or age class where the stand is periodically harvested with clearcut or shelterwood methods. This results in minimum diversity within a stand but maximum diversity between stands.

Management for diversity will be discussed considering the five silvicultural factors: (1) stand condition, (2) size of treatment area, (3) scheduling of treatment, (4) arrangement of treatment areas, and (5) effects of topography.

In managed forests, vegetative stand conditions create wildlife habitat; their value for wildlife is determined by treatment prescriptions. In many cases, desirable wildlife habitat can be prolonged with a minor impact on wood production. For example, using a 95 year even-aged rotation, regeneration can be delayed a few years to increase time in grass-forb and shrub conditions (chapter 11). Snag production can be maintained by limiting salvage, modifying commercial thinning prescriptions, and by retaining damaged leave trees as future snags. Additional details can be found in chapter 7 and appendices 18 and 19.

Different kinds of regeneration treatments can be used to maintain or enhance wildlife habitat. For example, regeneration by the seed tree method and not cutting the 5 to 10 seed trees left per acre, will leave these trees to become large snags and eventually dead and down material (fig. 5). For some time, the structure would be a two-storied stand with a scattered overstory which could be bald eagle habitat if located adjacent to large water bodies (chapter 13). Similarly, a heavy shelterwood might be treated with only partial removal of the residual trees, leaving 5 or 10 per acre to serve as future snags.

Modification of silvicultural treatment has previously been discussed in regard to creating old-growth stand conditions. The discussion was only an illustration using 80 leave trees per acre after the commercial thinning at age 95. More or fewer trees could be retained depending on site quality and wildlife habitat objectives.

Size of a treatment area is influenced by requirements of wildlife species for food, cover, water, and space. Chapter 6 discusses these requirements in some detail. Information on territory size and type of resident is contained in appendix 8; woodpecker territorial requirements are shown in chapter 7, tables 6 and 7.

In general, wildlife bird species richness increases as stand size approaches 84 acres. Then richness tends to decline with increasing size, due largely to a loss of edge effect (chapter 6, fig. 13). Size of area for species richness is about 3 times larger than the circular deer and elk optimum forage area (chapter 11).

Figure 5.—Four stand conditions: clearcut unit in foreground, dense sapling-pole, open shelterwood, and large sawtimber in the background. Partial shelterwood removal, leaving 5 to 10 trees per acre, would be one alternative for large snag production and later addition of 10 to 20 tons per acre of dead and down material to enhance wildlife habitat.

Thus, management for maximum diversity may lead to less than maximum populations of many species. Areas larger than 84 acres are needed for some species such as the northern spotted owl. Other wildlife territorial sizes that require special consideration are characterized in appendix 3, which includes threatened and endangered species, and appendix 13, which tabulates species use of special and unique habitats.

Land managers utilizing even-aged management in western Oregon and Washington should understand that harvest unit size will determine tract size of the succeeding stand conditions; i.e., hiding cover, thermal cover, large sawtimber stand conditions, and old-growth tract size. Areas selected for uneven-aged management also should be designated with certain minimum and maximum tract sizes for optimum diversity management.

Treatment scheduling is determined by selection of rotation length in even-aged management. For example, the 95 year rotation has about 15 percent of the land area in open habitat whereas a 400 year old-growth rotation only has 4 percent. The 95 year rotation of site index 90 calls for scheduling of two commercial thinnings, and the old-growth rotation should have three commercial thinnings and possible control of understory density to attain stand condition objectives at the desired age. These thinnings are required to promote height and diameter growth of trees which are essential for production of snags large enough to accommodate all cavity-using wildlife. The treatments must be scheduled over time because stand conditions change. Treatments can speed or slow this change depending on what prescriptions are applied and how many years have elapsed between treatments.

Scheduling also should consider time and space relationships in regard to optimizing diversity. If habitat for wildlife requiring open conditions for reproduction and feeding are to be enhanced in a drainage, for instance, clearcut regeneration units must be scheduled at least every 15 years to maintain open habitat.

Arrangement of treatment areas, which results in an arrangement of different wildlife habitat, is important for diversity. Increasing amount of edge and increasing contrast in edge results in greater diversity and thus increasing species richness (chapter 6). Appendix 17 provides a method by which diversity may be calculated for an area. An attempt should be made to shape units for edge and visual enhancement. Distance between stands of similar condition is important for maintaining viable populations, for example, 3 to 12 miles between northern spotted owl habitats, 2 to 2.5 miles between bald eagle habitats, and 1200 feet for deer and elk habitat.

Topography influences diversity in four ways: (1) The effect of topography on harvest and transportation systems, (2) effect of topography on animal distribution, (3) location and kind of water, and (4) different plant communities at different elevations.

Prescription of treatment to enhance wildlife habitat must consider timber harvesting methods. Topography suited to ground skidding equipment poses few problems for any of the other four silvicultural factors. Steep ground, however, presents some problems as discussed previously. For example, longline cable yarding systems economically suited to harvest old growth are generally not economically suited for commercial thinning of low volumes of small diameter material. Steep slopes greater than 2000 feet in length are particular problems if small size regeneration units are desired without midslope roads. Isolation of a unit away from a road requires skyline yarding logs over the top of the intervening stand, a tenuous situation, or yarding by helicopter or balloon which are very expensive. A midslope road would provide access for yarding but could increase the chance of landslides and sedimentation in streams as well as cause harassment and barriers to movement of animals. Therefore, application of silvicultural treatment to enhance wildlife habitat is often constrained by topography.

Where slopes exceed 60 percent and cable yarding is required, old growth might be allocated along a stream with a 95 year rotation planned for the slopes because they could be commercially thinned and yarded from an upslope road. This situation would provide large woody material for the stream structure and diversity needed by salmonids (see chapter 10), enhance riparian habitat, and offer travel corridors for wildlife. Adjacent regeneration units would provide maximum contrast of edge, would enhance diversity, and yarding would be simplified for commercial thinning. Other topographic considerations might be to maintain old-growth rotations on unstable land forms, broken, convex slopes difficult to cable yard, or other locations where economical commercial thinning is questionable.

Balancing Wildlife and Timber Management

Since timber production is a dominant land use west of the Cascade Crest in Oregon and Washington, silviculturists regularly make stand treatment prescriptions to enhance wood production and in doing so have a major influence on wildlife habitat. These prescriptions can be modified for maintaining or enhancing wildlife habitat by: (1) allocating a percent of land area by stand condition and plant community to various kinds of critical habitat in each management unit and (2) treatment of special and unique habitats.

The land manager might provide direction as follows: (1) forest land will be divided into 8,000 to 12,000 acre units (i.e., third or fourth order stream drainages) based on topographic characteristics. At least 5 percent of each area will be maintained in grass-forb, shrub and open sapling-pole conditions and 5 percent in old-growth in each plant community; (2) snags will be maintained at 40 percent of optimum level for primary excavators; (3) emphasize habitat for northern spotted owls, bald eagles, and deer and elk at defined levels. For example, 400 spotted owl management areas will be maintained on public lands in Oregon (chapter 12).

This kind of management direction can be evaluated at two levels of intensity depending on the wildlife objectives: (1) estimating general wildlife responses to alterations in special or unique habitats, plant communities, or stand conditions; and (2) predicting individual species reactions for reproduction and feeding. The next two sections deal with these approaches.

Wildlife Responses

General wildlife responses to alterations in special habitats or plant communities which result in stand condition changes in time and space can be evaluated from appendices 13, 14 and 15. Again using the temperate coniferous forest plant community as an example, appendix 14 shows that 203 species use this community for feeding and 182 species use this plant community for breeding. Examination of appendix 15 shows that of the 182 species using this plant community for breeding, 132 use the old-growth stand condition while 62 use the grass-forb stand condition. Old-growth is the primary breeding habitat for 77 species while grass-forb stand conditions are used as primary breeding habitat by 28 species. A regeneration harvest of the old growth can be expected to displace or eliminate most of the 77 species that use this stand condition as their primary habitat while gaining 28 new species in the grass-forb stand condition. Most of the displaced species will not return until plant succession on this unit reaches the large sawtimber stand condition.

The wildlife habitat management direction called for above was to provide at least 5 percent of the area in open habitats including grass-forb, shrub, and open sapling-pole, and 5 percent in the old-growth stand condition. Also snags were to be maintained at 40 percent of the optimum level for excavator species, and habitat for bald eagles, spotted owls and deer and elk would be emphasized at defined levels.

The 95 year rotation would provide 15 percent of the land area in open stand conditions, exceeding the 5 percent constraint, but would not provide the large sawtimber or old-growth stand conditions required to meet the other constraint. Both large sawtimber and old-growth stand conditions could be accommodated, however, with a 400 year rotation. A dual rotation, assigning 90 percent of the land area in the management unit to a 95 year rotation and 10 percent of the area to a 400 year rotation, would resolve both constraints.

The area managed on a 400 year rotation could be used to meet the habitat requirements of spotted owls and bald eagles, to provide optimal cover for deer and elk, woody material for stream habitat diversity, and to maintain the integrity of riparian zones. A portion, perhaps 5 percent, of the area allocated to the 95 year rotation could be harvested in 84 acre clearcuts to provide for maximum wildlife species diversity while the remainder could be harvested in 25 acre clearcuts to enhance deer and elk forage.

These proposed directions would provide for diversity. With only 15 percent of the land allocated to open areas and 5 percent to old growth, however, a majority of the area will be in closed sapling-pole sawtimber which provides little diversity for wildlife. Seventy percent of the 95 year rotation would be in this stand condition, or about 63 percent of the land area. Large sawtimber would occur between ages 100 and 200 in the old-growth rotation, about 25 percent of the rotation, and would occupy only 2-3 percent of the land area. Wildlife habitat would not be maximized but habitat for viable populations would be provided.

Suitable snags are critical for cavity-using species. Chapter 7 discusses the size, number per acre, laws regarding retention and falling of snags, systems for retaining them during harvest, and methods for creating snags. The 95 year rotation would provide about 500 snags per hundred acres larger than 12 inches but only 150 of these would be larger than 15 inches d.b.h. during the last 20 years, or about 20 percent of the rotation. The smaller snags are suitable for use only by downy woodpeckers. Old-growth rotations provide 78 percent of the optimum snags per hundred acres for all cavity users. Thus 20 percent of the 95 year rotation on 90 percent of the land, and 78 percent of the old-growth rotation on 10 percent of the land combined would provide about 19 percent of the optimum number of snags for cavity excavators and users (table 1).

The 40 percent criterion for snags requires increased snag production. This can be accomplished in several ways. Table 1 shows three possible alternatives for increasing snag production to the 40 percent level. The first involves reallocating the amount of land area assigned to the two rotations. By increasing the land area assigned to the old-growth rotation to 40 percent and dropping the area in the 95 year rotation to 60 percent, the 40 percent of optimum criterion for snag production would be achieved. This combination would provide about 11 percent of the area in the grass-forb, shrub, and open sapling-pole stand conditions, 20 percent of the area in old growth and 26 percent of the area in large sawtimber.

Table 1—Land allocation to timber management systems and corresponding snag production

Percent optimum snag production by management system	Percent of land area and corresponding percent of optimum snag production.			
95 year rotation = 12%	90% land = 11%	60% land = 8%		
120 year rotation = 30%				80% land = 24%
130 year rotation = 36%			90% land = 32%	
400 year rotation = 78%	10% land = 8%	40% land = 31%	10% land = 8%	20% land = 16%
	100% 19%	100% 39%	100% 40%	100% 40%

The second option maintains the 10 percent area assigned to the old-growth rotation but increases the rotation length on the remainder of the area from 95 years to 130 years. With this option five percent of the land area would be old growth, 10 percent in open stand conditions and 27 percent in large sawtimber. The third option represents a combination of the two listed previously. The land area assigned to an old-growth rotation is increased from 10 percent to 20 percent and the rotation length on the remainder of the area is increased from 95 years to 120 years. This option would provide about 11 percent of the area in open conditions, 22 percent in large sawtimber and 10 percent in old growth. All three options meet the 40 percent criterion for snags.

Although reducing commercial thinning in the 95 year rotation might appear to be a way of increasing snag production it probably would not be a practical alternative. Snags greater than 10 to 12 inches d.b.h. would not be increased. Instead, lack of stocking level control would cause reduced diameter growth and overproduction of smaller snags. Snags larger than 12 inches d.b.h. require time for the tree to grow, therefore, increasing the rotation length is a more productive alternative.

In all four of the management options shown in Table 1, it is assumed that all snags are removed during the regeneration harvest, thus creating a 75 year period in the rotations when none of the requirements for cavity-using wildlife species are being met. To bridge this gap, at the time of regeneration harvest, existing snags along with some live trees to become future snags might be retained. If 40 percent of the snag requirements for cavity-using species can be provided by residual snags and leave trees during this period, the constraints on land allocation and rotation length would be relaxed. In this case the examples provided could be used to meet a higher percentage of the optimum habitat requirements for cavity-using species.

Featured species also require attention to tract size for old growth, arrangement of the tracts, and topographic influences. Northern spotted owls need at least 300 acres of old growth at the nest site and a minimum of 700 additional acres within a 1.5 mile radius for foraging. Bald eagle nest sites must include a minimum of 30 acres with some tall overstory trees that extend above understory trees. Most eagle nest sites will be adjacent to large water bodies. These criteria modify constraints on size of area, arrangement of the tracts, and topographic considerations.

And finally, attention must be given to special and unique habitats such as riparian zones (chapter 4), and caves, cliffs, and talus (chapter 9). Another special wildlife requirement is dead and down woody material as discussed in chapter 8. These chapters are summaries and discussions of important items. Appendices contain detailed information: appendix 8 deals with each species habitat, nesting, feeding, and perching requirements, appendix 13 with special and unique habitats, and appendix 20 with wildlife use of dead and down material.

Predicting Species Reactions

If more detailed analysis is required on individual wildlife species, attention should be turned to appendix 8 which is a basic, detailed account of 414 wildlife species found west of the crest of the Cascade Range in Oregon and Washington. It lists their resident status, territory size, association with plant communities and stand conditions, use of dead and down material, special habitat requirements, and reproductive characteristics. Some of the characteristics are summarized in appendix 14 showing wildlife species relationships to plant communities and in appendix 15 to stand conditions.

Wildlife species versatility ratings are shown in appendices 8 and 16. Low versatility is a result of restricted habitat requirements for reproduction, feeding, perching, and constraints on territory size. The ratings are developed according to quality requirements for habitat, size of territory, number of stand conditions used, and number of plant communities used. Of the excavator species associated with temperate coniferous forests, most have medium or low versatility ratings because of constraints on nest site diameter, territory, and associated stand conditions.

For example, those species with a versatility rating of 12, considered low versatility, use a limited combination of 12 plant communities and stand conditions for breeding and feeding out of a potential of 42. The white-headed woodpecker in this group uses three different plant communities for both breeding and feeding and uses three stand conditions within those communities for breeding and feeding. This contrasts with the spotted owl which uses four different plant communities for both breeding and feeding but only one stand condition within those communities for breeding and three for feeding. An even greater contrast occurs with the cliff swallow that uses 11 different plant communities but only one

stand condition within those communities for feeding. Relating this information back to appendix 8 permits the land manager to predict the consequences of most habitat alteration to individual wildlife species.

Providing habitat alone is not sufficient for wildlife. Quality of the habitat is also important. Additional details for cavity-using species can be found in the appendices. Appendix 18 discusses wildlife species in relationship to cavities, both excavators and secondary users. Quality of the nesting habitat can be evaluated with appendix 19 with regard to snag size and nest height relationships preferred by the excavator species. Additional quality relationships for excavators is discussed in chapter 7 dealing with types of cavities and their use. Chapter 11, dealing with deer and elk, discusses seeding and fertilizing regeneration units to enhance quality while chapter 10 discusses means of improving salmonid habitat.

Territoriality is another factor that must be considered. Territorial requirements of the various species determines the size of tract they will use. Details on territorial requirements of excavator species appears in chapter 7, tables 6 and 7. Providing occasional snag patches on less than a minimum sized area may not provide suitable habitat for excavators.

Appendix 3 lists species that require special attention by law or direction–threatened, endangered, and sensitive species. Northern spotted owl, bald eagle, peregrine falcon, and Columbian white-tailed deer are listed by either the states of Oregon and Washington, the Federal Government, or both as threatened or endangered. Specific management requirements are discussed in chapters 12 and 13, and in appendices 8, 18, 19, and 21.

Summary

Both wildlife and timber management objectives can be accomplished in the managed forest. Featured species management and diversity management for species richness have been discussed. Clearly, the two systems are not synonymous. Featured species management will not provide habitat for species richness, and diversity management will not provide maximum numbers of all featured species. There are trade-offs in wildlife management depending on the wildlife species that are emphasized and there are trade-offs in timber management when wildlife habitat is enhanced.

A combination of approaches is needed because we cannot maximize everything. Silvicultural prescriptions are used to provide both wood fiber and wildlife habitat. The degree of trade-offs between wood production and wildlife species richness or numbers of featured species depends on management goals.

On public lands, management goals are prescribed by law and by the formal process of land management planning. It is not a question of providing both wildlife habitat and timber products—that is required by law. It is not a question if both can be provided because they can. Silvicultural treatment is required if we are to provide the appropriate types and distribution of wildlife habitat in conjunction with a sustained yield of wood products. The point is that land managers, silviculturists and wildlife biologists need the commitment to do both. Creative skill and cooperation is required by both the forester and biologist to describe optimum habitat conditions, to prescribe management objectives, and third and most important, to accomplish management on the ground. Objectives must be set, equitable trade-offs agreed to, and then action plans initiated and carried out to accomplish the goals.

References Cited

Curtis, R.O.; Clendenen, C.W.; DeMars, D.J. A new stand simulator for coast Douglas-fir: DFSIM user's guide. Gen. Tech. Rep. PNW-128. Portland, Or: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 79 p.

Ford-Robertson, F.C., ed. Terminology of forest science technology, practice, and products: English language version. Multiligual Forestry Terminology Series 1. Washington, DC: Society of American Foresters; 1971. 349 p.

Franklin, J.F.; Cromack, K., Jr.; Denison, W.; [and others]. Ecological characteristics of old-growth Douglas-fir forests. Gen. Tech. Rep. PNW-118. Portland, Or: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 48 p.

Heinrichs, J. Old growth comes of age. J. For. 81(12): 776-779; 1983.

Hemstrom, M.A.; Franklin, J.F. Fire and other disturbances of the forests in Mount Rainier National Park. Quaternary Reasearch. 18: 32-51; 1982.

Lambert, R.L. Biomass dynamics of dead Douglas-fir and western hemlock boles in mid-elevation forests of the Cascade Range. Corvallis,OR : Oregon State University; 1981. 152 p. Disertation.

15

Impacts on Wood Production

Herbert L. Wick
David Fauss
Ray Zalunardo

Table of Contents

Introduction

There is a close interrelationship between variables that affect wildlife habitat and variables that affect timber outputs. For a sound basis in making the trade-offs between wildlife habitat and timber production, managers need to be able to quantify as many of the competing demands as possible. The intent of this chapter is to present a sampling of the techniques currently available to the land manager for modeling the impact on wood production of management practices that provide for other resource concerns such as wildlife habitat. The techniques described are necessarily conceptual rather than concrete examples. The actual impact on timber outputs of a practice designed to meet other resource objectives will depend on the characteristics of the land base (distribution of age classes, stand composition, and site productivity) and the objectives of the landowner or land managing agency (spatial management, harvest technique, rotation, or minimum harvest age and importantly, the decision on even-flow or nondeclining yield).

The techniques described are basically those used by two federal land management agencies; the U.S. Department of Agriculture, Forest Service and the U.S. Department of the Interior, Bureau of Land Management. These techniques, however, could be applied by other owners who face similar decisions. Of specific interest are techniques that help determine the impacts of maintaining or providing old growth, snags, down woody material, travel routes and forage/cover needs for big game, and of stream protection and reduction of sediment loads for salmonids. Two conceptual approaches will be used: 1) impacts of decisions that can be modeled in yield tables developed for specific stands are compared to some "standard" yield tables that reflect outputs of timber from stands that were not managed to meet the special conditions; 2) a more complex approach where computer models are constructed to reflect special management direction (such as extended rotations for old growth) and the output from those computer models is then compared to outputs from a "standard run". One such model in current use by the USDA Forest Service is called FORPLAN. There are other similar models such as SIMIX, used by the Bureau of Land Management, and TREES developed by Oregon State University. FORPLAN will be referred to throughout the text because its use is widespread, but other modeling techniques are available and can be used in a similar way.

Evaluating Trade-Offs

Yield Table Adjustment Method

Impacts on timber output generally occur because of a reduction in the amount of volume recovered per acre. These reductions may result either from dedicating a portion of the volume to other uses such as snags and down woody material (fig. 1), or by altering cultural practices to provide specific wildlife habitat needs (i.e. opening stands to 60% crown closure at the time of the precommercial thinning operation to provide forage for deer and elk, or reducing the original planting density to delay canopy closure). Wick and Canutt (1979) provide a detailed discussion of the costs of using this process to provide snag habitat in ponderosa pine stands of northeastern Oregon.

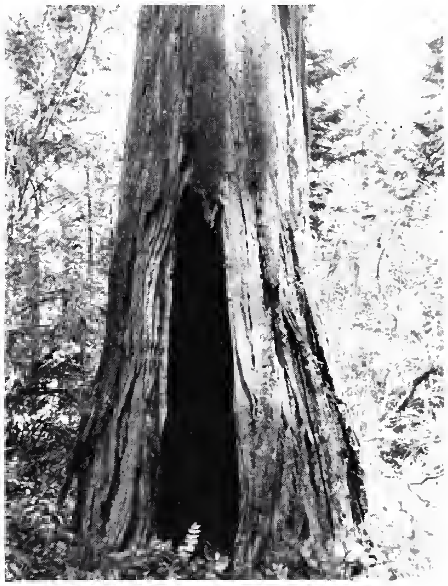


Figure 1.—Dedicating existing trees for wildlife habitat, such as this fire scarred incense cedar, results in a reduction in the maximum wood volume that can be recovered per acre.

Yield tables are used to forecast how much and what kind of wood products can be expected from managed stands. Such tables show the expected growth pattern of a managed stand for one or more tree species. The USDA Forest Service derives yield tables for managed stands by forecasting stand conditions at periodic intervals.

These descriptions of stand condition include data on mean stand diameter at breast height (d.b.h.), average tree height, number of stems per acre, form class, and mortality. From these data, the forest manager can calculate the wood volume to be removed in commercial thinnings and in the final harvest cut. Computer models such as DFSIM are commonly used to construct yield tables for Douglas-fir in the Pacific Northwest. Fortunately, certain wildlife habitat requirements can be assessed in terms of wood products foregone by examining variables used in the construction of yield tables for managed stands.

If snags and down woody material are to be maintained, it is necessary to adjust these "standard" yield tables to provide for trees that will eventually become snags and down woody material. It is the intent in stands managed intensively for timber production to maintain stocking density (number of trees per acre) through intermediate cuttings and to harvest trees before mortality occurs. It is necessary to depart from this strategy if snags for wildlife habitat are to be provided. To construct these yield tables, the following types of information are required: wildlife species being considered determines the size of snags needed, how long a snag will provide the desired habitat conditions, and growth characteristics of the stand. These factors will determine the stand age at which trees of the desired size will be produced and also, the rate and size of trees that will die to produce snags. Comparison of standard yield to the wildlife emphasis yield will then indicate the timber volume foregone to provide the desired wildlife habitat.

The impact of providing additional forage on timber yields can be assessed using a technique similar to that used in evaluating snag and down woody habitat protection or enhancement. A standard yield table is constructed for the stand, then a "special yield table" is developed that reflects the desired canopy closure (fig. 2). In this example, to increase the amount of forage for deer and elk, crown closure is reduced to 60 percent of full closure. This requires planting fewer trees, planting trees in clusters, precommercial thinning, or combinations of the preceding, which in turn reduces the number of trees available for commercial thinning at the

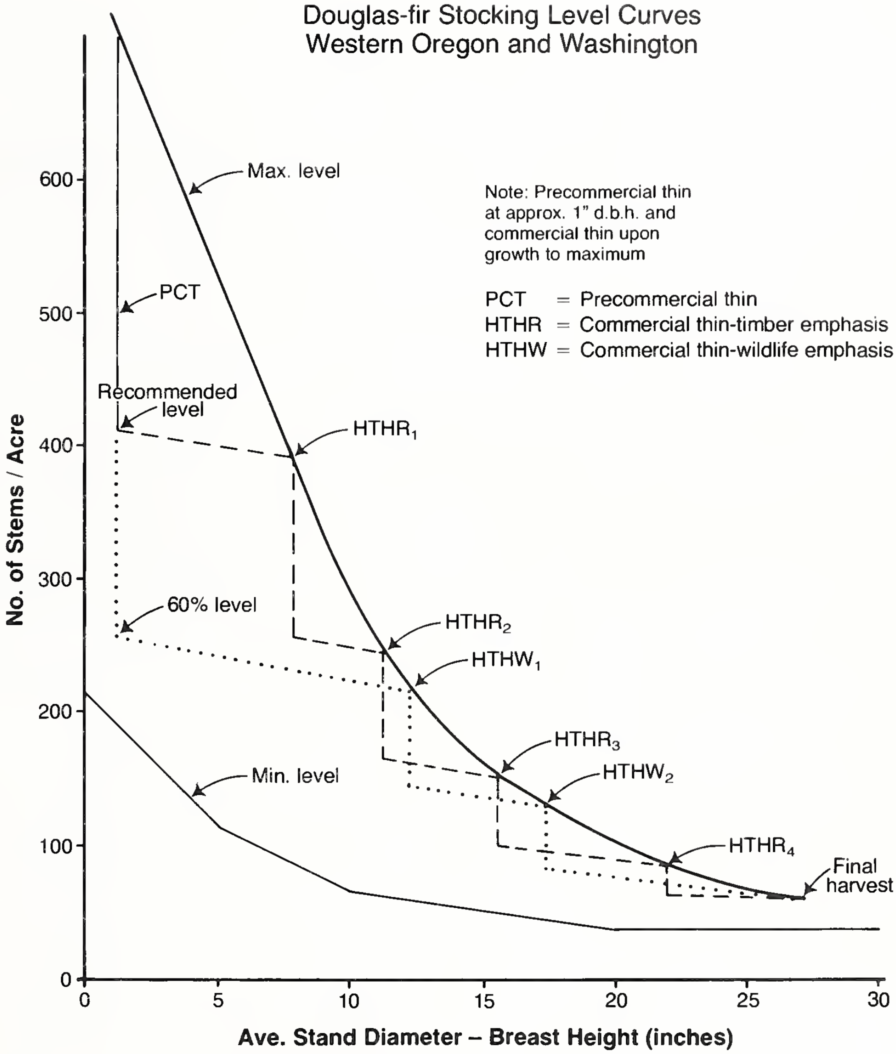


Figure 2.—A hypothetical relationship between number of stems per acre and average d.b.h. based on USDA Forest Service, Region 6 westside Douglas-fir stocking curves. The graph shows the range of stocking levels where acceptable timber growth is expected to occur. If stocking levels exceed the curve titled "Max. Level", growth loss occurs due to overstocking. If stocking levels are less than the curve titled "Min. Level", growth loss occurs from not fully utilizing the growing site. The curve titled "Recommended" shows stocking levels for a typical stand intensively managed for timber production. The curve titled "60% Level" shows stocking levels for a stand that is managed to lengthen time the site will produce big game forage. The significant impact on timber yield results from missing the first commercial thinning opportunity. It is important to note that precommercial thinning is not the only way to delay canopy closure. For example, on many sites the original planting levels could be reduced to 200-300 trees per acre and if natural regeneration did not occur to a significant degree, acceptable stocking to emphasize forage production would occur.

first scheduled entry (fig. 3). The analysis requires detailed knowledge of how the timber species involved respond to stocking density. The loss in volume due to reduced stocking will be partially offset by additional growth on the residual stems resulting from wider tree spacing. This special "yield table" would then be compared to the "standard" for the site.

Another example involves providing thermal and optimal cover for elk by altering rotation lengths and scheduling timber harvests at a rate that would maintain mature and old-growth timber. If rotations are lengthened to accommodate this need, there will be some loss of yield due to a reduction in the mean annual increment (MAI) (fig. 4).

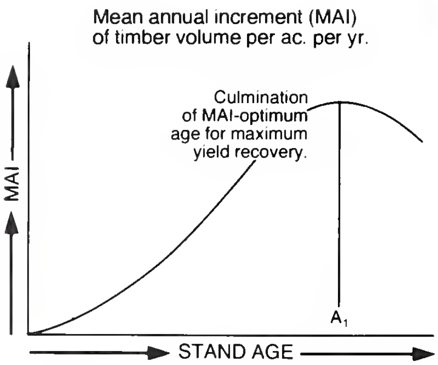


Figure 4.—A hypothetical relationship between stand age and wood volume produced on a per acre per year basis. The shape of the curve will vary depending on species, original stocking density, stand age and number of trees cut at time of precommercial thinning, stand age and amount of volume removed at commercial thinning, and utilization standards. The shape of the curve will be different for different conditions. The important point is that yield is less when the stand is cut either before or after culmination of mean annual increment.

As can be seen from figure 4, entries can be either before or after the optimum age for maximum recovered volume. To achieve a desired distribution of age classes, it might be necessary to harvest some areas before the culmination of MAI. For example, it may be desirable to have 10 percent of the area in an early seral stage (0-10 years old) for big game forage. To maintain 10 percent of the area in age class 0-10 requires that

Figure 3.—Lower initial stocking densities designed to prolong the period of prime forage production for big game probably will have little affect on wood volume available for final harvest but may reduce commercial thinning volumes.

10 percent of the area be harvested each decade. This results in a rotation age of 100 years. If the stand produced its optimum volume per acre per year (culmination of MAI) at an age significantly different than 100 years there would be a reduction of mean annual increment (less volume recovered per acre per year) due to harvesting the stand before or after optimum yield is achieved.

Providing a specific wildlife habitat requiring a tree of a larger diameter than that produced at the culmination of MAI would result in a reduction in timber volume produced. To measure this, determine the stand age where the desired average stem diameter occurs (fig. 5). Use this stand age in conjunction with figure 2 to determine MAI and then compare this MAI with the MAI at culmination. The difference between the two represents the impact of the wildlife practice on maximum wood production.

There are other examples of yield table type adjustments but the method for assessing their impacts are similar. As rotation lengths are either lengthened or shortened to achieve habitat or other needs, the impact on timber yield is calculated by the formula:

$$\left[\frac{1 - MAIo - MAIa}{MAIo}\right] \times 100 =$$

percent of optimum yield recovered

Where: MAIo is the mean annual volume increment at optimum age for timber production, and MAIa is the mean annual volume increment at adjusted age to achieve wildlife habitat or other similar objectives.

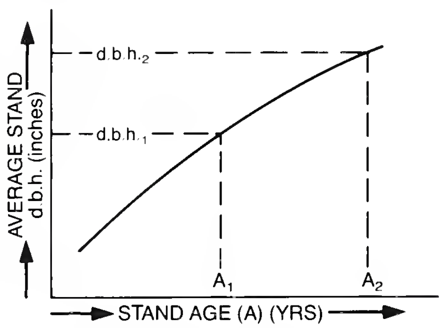


Figure 5.—A hypothetical relationship between stand age and average stand d.b.h. For example, if an average tree d.b.h.$_2$ is desired that is larger than the d.b.h.$_1$ of the tree produced at the stand age (A_1) where maximum timber volume is produced, the stand age will be extended to A_2. To calculate actual volume impact, you would use the stand ages A_1 and A_2 along with known data such as illustrated in figure 2 to determine the relationship between between mean annual volume increment and age.

This model deals only with the physical ability of an acre to produce wood and is probably the easiest of the reductions to visualize. In the complex business of planning harvest levels there are other constraining factors that contribute to the analysis. One of these factors is the requirement for sustained yield non-declining evenflow of forest products. This simply says that an area such as a given National Forest will provide the same volume of timber every year throughout the planning period. Forest Service and Bureau of Land Management policy allows for some departures from sustained evenflow but usually departures will be limited because of a number of considerations such as "cumulative effects" on a drainage. These departures will at best reduce impacts, not eliminate them. In effect, this translates impacts on output in any one decade to all the rest of the decades. To assess long-term impacts, a modeling technique similar to FORPLAN, TREES, or SIMIX needs to be used.

Computer Modeling Method

To demonstrate computer modeling, the use of FORPLAN will be discussed. Most forest plans that are currently being prepared by the USDA Forest Service use the FORPLAN computer model to calculate outputs from the forest. The model describes the forest as it exists. Lands are grouped into allocation classes that have similar characteristics. Output coefficients are assigned and constraints applied.

One of the major scheduling objectives in the National Forest system specifies that National Forests be managed to limit the sale of timber each decade from each National Forest to a quantity equal to or less than that which can be removed each decade in perpetuity (sustained yield). Management direction also includes other resource objectives such as limiting the amount of sediment produced from road building and logging to some specific amount per year. This limits potential solutions for other outputs (timber production, forage production, recreation visitor days, etc.) to those that generate sediment outputs within the acceptable range. Figure 6 illustrates this relationship for sediment yield and timber harvest. To model this, a mathematical relationship must be developed between sediment production and timber harvest. This is usually accomplished through the use of a combination of research data and practical experience. There is a unique relationship between sediment production and timber yield for each planning area and these relationships can be modeled. From this, figure 6 shows that the range of acceptable timber volume available for sale is limited to volumes less than V_1.

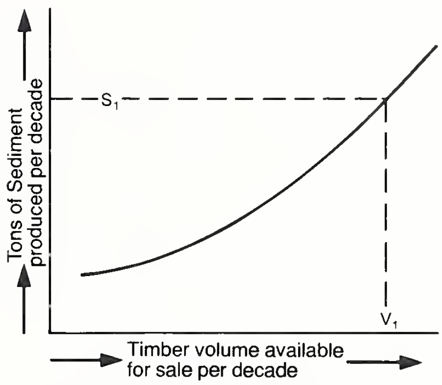


Figure 6.—A hypothetical relationship of sediment production associated with varying levels of timber output. Actual values for this relationship can be calculated from FORPLAN runs. The graph indicates that a decision to limit sediment production will also limit timber production.

Meeting the requirements of spotted owl habitat in the most economically efficient manner is another good example of effects that can be modeled with FORPLAN. There are three basic approaches to providing this habitat. One is to dedicate an area of land for spotted owl habitat where no attempt will be made to recover any timber volume. The second approach is to dedicate a large number of acres to be managed on extended rotations for spotted owl habitat. The third approach would involve a combination of the first two approaches. The simplest approach for evaluating this objective (yield table adjustment method) would be to compare the mean annual volume production of the same area under the two different management regimes. An example is shown in figure 7.

The approach outlined above provides a good approximation of the effect on timber yield on the specific acres involved, but to determine the cumulative effect on planned timber yields for the management area, both strategies must be modeled and results compared. This would require developing yield tables for extended rotations and using them for the portion of land managed for old-growth habitats, then comparing outputs with a model run where the acres dedicated for old growth had been removed from the land available for timber production.

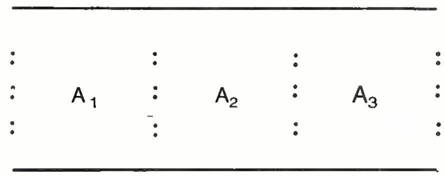


Figure 7.—An example of how land might be allocated to provide old growth for spotted owl habitat. Under the dedicated area concept, area A_1 could be dedicated in perpetuity to old-growth habitat while areas A_2 and A_3 would be managed under full production. Under the managed habitat strategy, all three areas would be managed on extended rotations. To provide the desired habitat through time it would be necessary to have one area in a young age class, one in a mature age class, and one in an old-growth age class. To compare impacts using yield tables, compare the average volume produced per year for the total area (A_1, A_2, and A_3) under both strategies. The number of areas managed under extended rotations is governed by the length of the rotation and that portion of the area that it takes to meet old-growth habitat requirements. In the example above, it was assumed the rotation extended for 240 years and that old-growth habitat conditions existed from age 160 to 240 years. If the stand did not provide suitable old-growth habitat conditions until age 180, it would be necessary to manage 4 areas on the extended rotation with portions being in the 0-60, 60-120, 120-180, and 180-240 year age classes. There are many combinations of rotation length and area that can be used to meet these objectives.

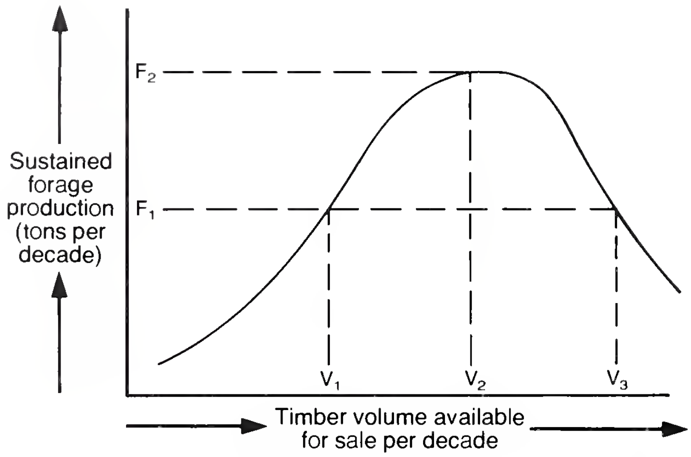


Figure 8.—A hypothetical relationship between tons of forage produced per decade and volume of timber sold per decade through the planning period. Actual values for this relationship can be calculated from FORPLAN runs and will vary for each area depending on species providing forage, timber species, and growing conditions. It is interesting to note that there is usually only one sale volume per decade (V_2) where forage production through time is maximized (F_2). If a minimum forage level is acceptable such as F_1, there is a wide range V_1 to V_3 of possible volume outputs.

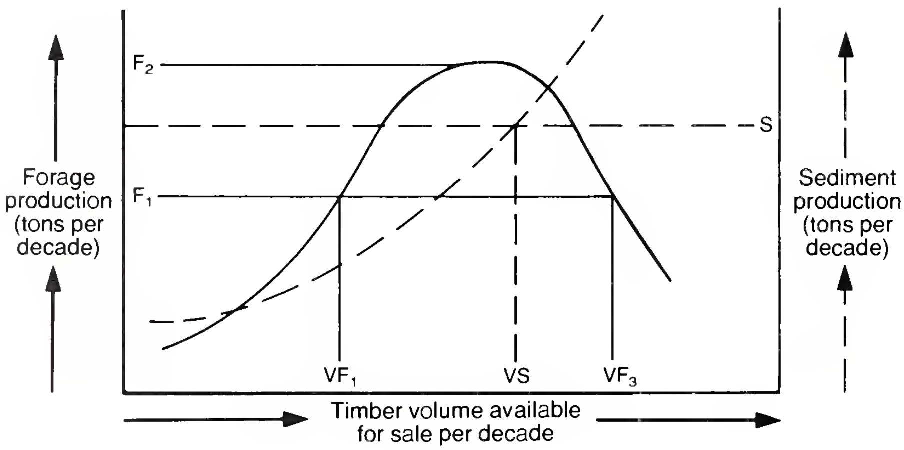


Figure 9.—A hypothetical relationship where both tons of forage and sediment yield constraints are applied simultaneously. The decision options in terms of saleable volume is greatly constrained. The options where forage requirements will be satisfied fall between VF_1 and VF_3 but where both forage and sediment requirements are satisfied the harvest volume is limited to the range between VF_1 and VS.

The FORPLAN model has the capability of regulating timber output, but can also be developed to allow for the production of a uniform amount of wildlife forage per decade (fig. 8), restrict sedimentation to a prescribed level, provide the environment needed to enhance recreational visitor days, etc. Such objectives can be examined collectively or individually, and the difference in yield compared with a model run that optimizes only timber production. The difference in yields is the opportunity cost of the difference in objectives. As each additional constraint is applied, the decision options in terms of volume available for sale may be reduced.

As mentioned earlier, the FORPLAN model is an analysis technique used to calculate timber output as well as several other outputs (sediment, recreation visitor days, dollars, etc.). With this model, the composite impact of scheduling demands, resource constraints, and adjustments in timber yield tables come together to illustrate the cumulative impact of management decisions on timber outputs. Figure 9 illustrates how the cumulative impact of forage production and sediment yield impact timber outputs. With additional constraints, the options on timber outputs are further reduced.

Computer models have enabled the land manager to bring together many land-use decisions, current research data on cause/effect relationships, and site specific conditions. Care must be taken in interpreting the results produced by computer models since they are stated in very precise terms; however, they are no more accurate than the data and assumptions that went into the model. Also, the model information means little until it has been applied on the ground and the results verified.

Summary

It has become both easier and more complex to assess the impacts of management decisions. Assessment is easier in the respect that there are modeling tools available to make these comparisons, but more complex in that analysis requires more time and dollars and the data requirements are much larger (yield tables need to be constructed to reflect management strategies and output coefficients need to be developed that relate strategies to a wide range of outputs - not just timber, but tons of forage, sediment, visitor days, etc.).

If forest lands are to be managed to produce a spectrum of outputs – wildlife habitat, recreational oportunities, timber, etc. – it is necessary for the manager to be proactive and plan for them. They will not necessarily be produced at the desired times or levels unless we do. It is also important for land managers to remember that planning and modeling are preliminary steps and that it is critical to follow through with specific practices to provide the desired forest conditions.

It is useful again to recall two of Commoner's (1971) "laws" of ecology: "everything is connected to everything else," and "there is no such thing as a free lunch." Those concerned with the management of the timber resource should be aware that their actions impact wildlife and their habitats, while those concerned with wildlife in the managed forest should be aware that adjustments in forest management for the welfare of wildlife have impacts on wood production.

These "laws" of ecology might just as well be called "laws" of economics. Adjustments in forest management schemes to provide wildlife habitat often result in some loss of wood available for harvest. This type of loss can readily be related to dollars and jobs. Wildlife habitat destruction or preservation may also translate to dollars and jobs but these values are much more difficult to measure in economic terms.

The prudent manager of public forest lands, operating under the multiple use management concept, must evaluate the benefits and costs of providing wood products and wildlife habitat. All multiple use forest management takes place in an environment where trade-offs are the standard operating procedure. These trade-offs are appropriate only when the manager is able and willing to honestly compare all benefits and costs for both wildlife and wood products.

References Cited

Commoner, B. The closing circle: Nature, man, and technology. New York: Alfred A. Knopf; 1971. 326 p.

Wick, H.L.; Canutt, P.R. Impacts on wood production. In: Thomas, J.W., tech. ed. Wildlife habitats in managed forests; the Blue Mountains of Oregon and Washington. Agric. Hand. 553. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979: 148-161.

Glossary

abiotic—the nonliving components of the environment, such as air, rocks, soil, water, peat, plant litter, etc. (Schwarz et al. 1976).

alevin—a stage of embryonic development of salmon or related fish referring to fish recently hatched from the egg and before absorption of the yolk sac and emergence from the spawning gravel (Toews and Brownlee 1981).

anadromous fish—species which migrate from the sea to spawn in fresh water, their offspring return to the sea and spend most of their adult lives there, e.g., salmon and steelhead.

animal damage—injuries inflicted upon forest tree seed, seedlings, and young trees through seed foraging, browsing, cutting, rubbing, or trampling; usually by animals, but sometimes birds.

aquatic—growing or living in or upon water (Webster 1977).

aquatic ecosystem—a body of water, including all the organisms and nonliving components, that functions as a natural interacting system.

aquatic habitat—habitat that occurs in free water (Thomas 1979).

aquatic zone—an area covered by water (Thomas 1979).

basal area—the area of the cross section of a tree stem near its base, generally at breast height (4.5 ft.) above the ground and inclusive of bark (Ford-Robertson 1971).

bedload—sediment (sand, gravel or heavy rock fragments) that moves by sliding, rolling or bouncing on or very near the bed of a stream, or along the bottom of an estuary or the ocean.

benthic—relating to the bottom of a body of water (lake, river, estuary, ocean); includes substrate and overlying portion of water within one meter of substrate (Proctor et al. 1980).

benthos—the animal and plant life that inhabit the bottom of the sea, a lake, stream or other aquatic habitat.

big game—a designation used by state wildlife agencies for large mammals some of which are hunted; e.g., deer, elk, bear; while others, such as the endangered Columbian white-tailed deer, are fully protected.

biochemical oxygen demand (BOD)—the amount of oxygen required to stabilize demands from aerobic biochemical action in the decomposition of organic matter.

biomagnification—the step-by-step increasing concentrations of substances in successive trophic levels of food chains; commonly reported only for harmful substances; e.g., pesticide residues.

biomass—the total quantity of living organisms of one or more species in a community or per unit of space, often expressed as weight per unit of volume or area (adapted from Thomas 1979).

biota—the flora and fauna of a region or area.

biotic—the living components of the environment.

blowdown—a tree or trees uprooted or felled by the wind (Ford- Robertson 1971).

broadcast burning—intentional burning in which fire is intended to spread over a specific area (USDA Forest Service 1956).

buffer strip or zone—an area of vegetation left or managed to reduce the impact of a treatment or action of one area on another (Thomas 1979).

cable yarding—a method of transporting logs from the point of felling to a central location or landing by use of a steel cable attached to a powered winch; variations of this system include high-lead yarding, and skyline yarding.

canopy—the more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody growth (Ford-Robertson 1971).

canopy closure—the progressive reduction of space between tree crowns as they spread laterally (Ford-Robertson 1971); a measure of the percent of potential open space occupied by the collective tree crowns in a stand (Thomas 1979).

cat yarding—see tractor yarding.

cavity—a hole or opening in a snag or living tree caused by fire, rot, limb breakage, or excavated by birds; used for roosting, reproduction, and foraging by many birds and mammals.

cavity excavator—a species that digs or chips out cavities in wood to provide itself or its mate with a site for nesting, roosting, or foraging (adapted from Thomas 1979).

cavity nesters—wildlife species that nest in cavities (Thomas 1979).

channel—a natural depression that conveys water; a ditch excavated for the flow of water.

channel aggradation—building up of a streambed by sedimentation.

chaparral—a brush community composed of evergreen, sclerophyllous (firm-leaved) species; e.g., manzanita, ceanothus, etc.

clearcut—the removal of the existing forest stand in one operation and usually followed by establishment of the new stand by natural or artifical means (adapted from USDA Forest Service 1981e); an area from which all trees, merchantable or unmerchantable, have been cut.

climax—the culminating stage in plant succession for a given site where the vegetation has reached a highly stable condition (Ford-Robertson 1971).

climax vegetation—the final vegetative community which emerges after a series of successive vegetational stages and perpetuates itself indefinitely unless disturbed by outside forces.

closed sapling-pole-sawtimber stand condition—a stand condition in the forests of western Oregon and Washington where trees are passing through the sapling and pole sizes and entering the sawtimber size, and where there is a closed crown canopy; average stand diameter is between 1 and 21 inches d.b.h., and crown cover exceeds 60 percent.

codominant trees—trees in a forest stand that are not quite as tall as the dominant trees, yet have large crowns and are rapid-growing; together with dominant trees they comprise the main canopy of the stand.

commercial forest land—forest land that is now producing or is capable of producing at least 20 cubic feet per acre per year of commercially important tree species.

commercial thinning—the removal of a portion of the merchantable material from a forest stand.

community—a group of one or more populations of plants and animals in a common spatial arrangement; an ecological term used in a broad sense to include groups of various sizes and degrees of integration (Hanson 1962).

computer letter code or **species code**—a code of four to six letters for the binomial or scientific name of each vertebrate; the first two letters of the genus name and the first two letters of the species name make up the basic code (e.g., Cervus elaphus or CEEL); to resolve occasional conflicts, one or two additional letters from either the genus or species names are added.

conifer—an order of the botanical group Gymnospermae, comprising a wide range of trees, mostly evergreens that bear cones and have needle shaped or scale-like leaves; timber commercially identified as softwood (Ford- Robertson 1971); in western Oregon and Washington, the most important fiber-producing conifers are Douglas-fir and several species of pine, hemlock, spruce, true fir and cedar.

coniferous forest—a forest dominated by cone-bearing (conifer) trees (Thomas 1979).

conspecific—separate individuals or populations of the same species.

constraint—the state, quality, or sense of being restricted to a given course of action or inaction; something that restricts, limits, or regulates (Morris 1976).

contrast—in wildlife management, the degree of difference in vegetative structure along edges where plant communities meet or where successional stages or vegetative conditions within plant communities meet (Thomas 1979).

cover—vegetation used by wildlife for protection from predators, or to ameliorate conditions of weather, or in which to reproduce (Thomas 1979); fish cover may consist of deep water, undercut banks, submerged logs, or overhanging vegetation.

critical habitat—that portion of the living area of a species that is essential to the survival and perpetuation of the species either as individuals or as a population.

crown—the upper part of a tree or other woody plant, carrying the main branch system and foliage (adapted from Ford-Robertson 1971).

crown closure—see canopy closure.

crown cover—the amount of canopy provided by branches and foliage of trees, shrubs, and herbs in a plant community; may be specified by species, kind of plant, or collectively (Thomas 1979).

cull—a green tree, snag, or log that is nonmerchantable or of low economic value because it does not meet certain minimum specifications.

cultural practices—operations undertaken to assist the establishment of tree regeneration and to promote the growth of the forest crop; includes weeding, non-commercial thinning and/or poisoning of unwanted growth (adapted from Ford-Robertson 1971).

cutting unit—an area on which the trees have been, are being, or are planned to be cut.

d.b.h.—see "diameter breast high."

dead and down woody material—all woody material, from whatever source, that is dead and lying on the forest floor (Thomas 1979).

debris (organic)—used primarily in relation to fisheries: logs, trees, limbs, branches, bark, and other woody material that accumulates in streams or other water bodies; may be naturally occurring or the result of logging or road construction (Toews and Brownlee 1981).

decadent—deteriorating; when used in reference to stand condition there are inferences of the loss of trees from the overstory and of the presence of disease, or indications of loss of vigor in dominant trees so that the mean annual increment is negative (Thomas 1979).

decay—in wood, the decomposition by fungi and other micro-organisms resulting in softening, progressive loss of strength and weight, and changes in texture and color (Ford-Robertson 1971).

deciduous—pertaining to any plant organ or group of organs that is shed naturally; perennial plants, trees and shrubs that are leafless for some time during the year (Ford-Robertson 1971).

detrital energy base—energy derived from finely divided organic particles (detritus).

detritus—organic debris derived from decomposing plants and animals.

diameter breast high (d.b.h.)—the standard diameter measurement for standing trees, including bark, taken at 4.5 feet above the ground (Ford-Robertson 1971).

diversity—the relative degree of abundance of wildlife species, plant species, communities, habitats, or habitat features per unit of area (Thomas 1979).

diversity index—a number that indicates the relative degree of diversity in habitat per unit area (Thomas 1979).

dominant trees—trees in a forest stand whose crowns rise above the general level of the canopy; such trees usually have broad crowns and heavy limbs; also, the most numerous tree species occurring on an area; trees in a forest stand which exert the most influence on the environment.

drumming—the reverberating sounds made by a woodpecker while tapping rapidly on a suitable surface, such as a snag, or by a ruffed grouse beating his wings rapidly (adapted from Thomas 1979).

ecological niche—the place or position that a particular plant or animal occupies in the ecosystem with regard to its interactions with other organisms and the utilization of its environment.

ecology—the study of the interrelationships of biotic and abiotic communities with one another.

ecosystem—an interacting natural system including all the component organisms together with the abiotic (non-living) environment (Hanson 1962).

ecotone—the area influenced by the transition between plant communities or between successional stages or vegetative conditions within a plant community (Thomas 1979).

edge—the place where plant communities meet or where successional stages or vegetative conditions within plant communities come together (Thomas 1979).

edge effect—the increased richness of flora and fauna occurring in the transition zone where two plant communities or successional stages meet and mix.

emergent vegetation—aquatic plants which are not totally submerged; typically, they are rooted in an aquatic environment but most of the photosynthesis occurs above water; e.g., cat-tails (Proctor, et al. 1980).

endangered species—a plant or animal species which is in danger of extinction throughout all or a significant portion of its range because its habitat is threatened with destruction, drastic modification, or severe curtailment, or because of overexploitation, disease, predation, or other factors; federally endangered species are officially designated by the U.S. Fish and Wildlife Service and published in the *Federal Register* (adapted from Thomas 1979).

endemic—native or confined to a certain region; having a comparatively restricted distribution (Morris 1976).

environment—the sum total of all the external conditions that may influence organisms (Hanson 1962).

environmental factor—any influence on the combined plant and animal community (Thomas 1979); all the abiotic and biotic factors of a site (Ford-Robertson 1971).

ephemeral streams—streams that contain running water only for brief periods in direct response to precipitation (adapted from Thomas 1979).

epiphytic plant—a plant which derives its moisture and nutrients from the air and rain and usually grows on another plant (Webster 1977).

estivation—a state of dormancy or torpor during the summer or periods of drought (Morris 1976).

estuary—a coastal inlet where salt water meets fresh water, as at a river's mouth (adapted from Webster 1977).

even-aged stand—a natural forest stand or a managed one in which trees are produced or maintained with relatively minor differences in age (adapted from Ford-Robertson 1971).

evenflow—the relatively constant undiminishing supply of timber maintained from year-to-year for the planning cycle of a designated area.

evergreen hardwoods—broad-leaved hardwood trees whose foliage persists for several years; the most important evergreen hardwood trees of western Oregon and Washington are Pacific madrone, tanoak, chinkapin, canyon live oak and California-laurel; also a plant community described in this handbook (see chapter 2 and appendix 5).

extensive forest base—all commercial forest land within a designated area; including areas where harvesting is restricted, such as riparian zones, fragile sites and administrative withdrawals.

featured species management—a wildlife management strategy to produce relatively high numbers of selected wildlife species in particular places for particular purposes (Thomas 1979).

fiber—see wood fiber.

fireline—part of a fire control line from which flammable materials have been removed by scraping or digging to mineral soil; also called a fire trail (USDA Forest Service 1956).

flora—the plant population of a particular area; a list of plant species (with descriptions) of a particular area arranged in families and genera, together with a key to aid identification (Abercrombie et al. 1964).

food chain—the transfer of food energy from the initial source in plants through a linear series of organisms by repeated eating and being eaten; "food chains" are not isolated sequences but are interconnected with one another to form food webs.

food web—the interlocking pattern of food chains that results from their interconnection with one another and that illustrates the multipath transfer of energy in an ecosystem; a conceptual or graphic way of presenting the flow of energy through an ecosystem.

forage—vegetation used for food by wildlife, particularly ungulate wildlife and domestic livestock (Thomas 1979).

forage area—used primarily in relation to big game: an opening in a forest, natural or man-made, where ungulate wildlife and livestock feed on vegetative material.

forb—any herbaceous plant species other than those in the Gramineae, Cyperaceae, and Juncaceae families (Kothmann 1974); fleshy leaved plants (Thomas 1979).

forest—generally, an ecosystem characterized by tree cover; more particularly, a plant community predominantly of trees and other woody vegetation, growing closely together; an area managed for the production of timber and other forest products; or maintained in forest cover for such indirect benefits as protection of watershed areas or recreation (Ford-Robertson 1971).

forest ecosystem—a forest and its interacting component organisms together with the abiotic (nonliving) environment.

forest succession—the orderly process of change in a forest as one plant community or stand condition is replaced by another, evolving towards the climax type of vegetation.

fry—recently hatched free-swimming fish up to one year of age.

fuel loading—the amount of combustible material present per unit of area (Thomas 1979).

full cable suspension—a cable yarding system capable of lifting and transporting logs above the ground and vegetation to a landing, resulting in minimum disturbance to the environment; not all cable yarding systems have this capability.

function—the natural or proper action for which an organism or habitat or behavioral action is fitted or employed (Thomas 1979).

fungal conk—a fructification of a wood-destroying fungus which projects beyond the substrate (Ford-Robertson 1971); commonly referred to as a "conk."

fungi—mushrooms, molds, yeast, rusts, etc.; subdivision of Thallophyta; simply organized plants, unicellular or made of cellular filaments called hyphae, lacking chlorophyll; reproduce sexually and asexually with the formation of spores; many are microscopic, though some fruiting bodies reach a larger size; saprophytes or parasites of other plants and animals; take part with other soil

organisms in decomposition of plant and animal residues; important as agents of many plant and some animal diseases (Abercrombie et al. 1964).

game—species of vertebrate wildlife hunted by man for sport (Thomas 1979).

geomorphology—study of landforms including such characteristics as elevation, slope, aspect, etc.

grass—any plant species that is a member of the family Gramineae (Kothmann 1974).

grass-forb stand condition—a stand condition in the forests of western Oregon and Washington dominated by grasses and forbs; tree regeneration is generally less than five feet tall.

group selection—a modification of the selection system in which trees are removed in small groups rather than individually (Ford-Robertson 1971).

guild—a group of plants or animals that have ecological interrelationship and a similar mode of life; e.g., species which use tree boles for nesting.

habitat—the sum total of environmental conditions of a specific place occupied by plant or animal species or a population of such species (Thomas 1979).

habitat component—a part of an area or type of environment in which an organism or biological population normally lives or occurs (adapted from Thomas 1979).

habitat diversity—a mix of the component parts found within a particular habitat; e.g., in a salmonid habitat, the pools, riffles, cover, etc.; also the number of different types of habitat within a given area.

habitat niche—the peculiar arrangement of food, cover, and water that meets the requirements of a particular species (Hanson 1962).

habitat richness—the relative degree of ability of a habitat to produce numbers of species of either plants or animals; the more species produced the richer the habitat (Thomas 1979).

habitat type—the aggregate of all areas that support, or can support, the same primary vegetative climax; a classification of environmental settings characterized by a single plant association; the expression through the plants present of the sum of the environmental factors that influence the nature of the climax (Daubenmire 1976).

habituation—the gradual change in response to a stimulus as a result of prolonged exposure to the stimulus.

hard snag—a snag composed primarily of sound wood, generally merchantable (adapted from Thomas 1979).

hardwood—broad-leaved trees belonging to the botanical group Angiospermae; the wood produced by these trees, and distinguished from softwoods by the presence of vessels (Ford-Robertson 1971); in western Oregon and Washington, the most important hardwoods are red alder, Oregon ash, black cottonwood, Pacific madrone, chinkapin, tanoak, California-laurel, and several species of maples, oaks, and willows.

harvest—removal of wood from the forest for utilization; comprised of cutting and, sometimes, initial processing and extraction of trees from the forest (Ford-Robertson 1971); also used in reference to the take of game birds and animals.

heart rot—any rot in a tree confined to the heartwood, associated with fungi such as Fomes and Polyporus species; generally originating in a living tree (Ford-Robertson 1971).

heartwood—the inner layers of wood which, in a growing tree, have ceased to contain living cells and in which the reserve materials (e.g., starch) have been removed or converted into more durable substances (Ford-Robertson 1971).

hematology—the study of blood and its diseases (Webster 1977).

herbaceous ground cover—vegetation growing close to the ground that does not develop persistent woody tissue, and lasting, usually, for a single growing season; commonly referred to as "herbs."

herbicide—a chemical used to control, suppress, or kill plants, or to severely interrupt their normal growth processes (Beste 1983).

heterogeneous stand—a multilayered forest stand in which a large diversity of structural levels exist; such stands are often uneven-aged.

hibernation—the state of torpidity or inactivity in which some animals pass the winter (Morris 1976).

hiding cover—any vegetation capable of hiding 90 percent of a standing adult deer or elk from the view of a human at a distance of 200 feet or less; generally, any vegetation used by wildlife for security or to escape from danger (adapted from Thomas 1979).

high-lead yarding—a cable yarding system utilizing a spar or tower in order to provide lift to one end of the logs as they are dragged across the ground to a landing; suitable for yarding at distances of up to 1200 feet.

high temperate coniferous forests—(also see temperate coniferous forests) mid to upper elevation coniferous forests which differ from temperate coniferous forests by their significant winter snowpack and their short and cool growing season; also a plant community described in this handbook (see chapter 2 and appendix 5).

hole nesters—see cavity nesters.

home range—the area which an animal traverses in the scope of normal activities; not to be confused with territory (Thomas 1979).

hydrologic—pertaining to the quantity, quality and timing of water yield from forested lands (USDA Forest Service 1981e).

hydroperiod—the period of time when flooding occurs in riparian zones and wetlands, including the frequency of such events.

hydrophytes—plants which grow in association with water or in soil too saturated for most plants to survive; e.g., cat-tails.

igneous rocks—rocks formed from the cooling and solidification of molten material.

impact—the effect of one thing upon another (Morris 1976).

increment—the increase in girth, diameter, basal area, height, volume, quality, or value of individual trees or crops over a specified time, usually annually (Ford-Robertson 1971).

indicator species—in wildlife management, the welfare of a selected species is presumed to indicate the welfare of other species (Thomas 1979).

indigenous—flora or fauna that is native (not introduced) to an area.

induced edge—an edge that results from the meeting of two successional stages or vegetative conditions within a plant community; created by management action; e.g., a timber harvest, etc. (adapted from Thomas 1979).

inherent edge—an edge that results from the meeting of two plant community types; e.g., at the boundary between a forest stand and a natural meadow.

insecticide—a pesticide for control of insects.

insectivorous—an animal that eats insects (Hanson 1962); in common usage, includes animals and birds that eat insects and, sometimes, other selected invertebrates (adapted from Thomas 1979).

insolation—radiation from the sun received by the earth's surface (Webster 1977).

intensive forest base—commercial forest land, within a designated area, managed for sustained yield of wood fiber through the use of various silvicultural methods.

intensive forestry—the practice of forestry to obtain a high level of volume and quality of wood products per unit of area; accomplished through the application of the best techniques of silviculture and management (Ford-Robertson 1971).

intensively managed forest stand—a forest managed in order to attain maximum growth through application of silvicultural practices, including thinning, fertilization, and reduction of competition.

interspecific—interrelationships between members of separate species.

interstitial spaces—voids between substrate particles in a streambed.

intertidal—pertaining to that part of the shoreline of estuaries and oceans between mean low water (tide) and mean high water (tide).

intraspecific—interrelationships among members of the same species.

invertebrate—an animal lacking a spinal column (Hanson 1962).

lagomorphs—gnawing mammals of the order Lagomorpha which have two pairs of incisors in the upper jaw, one behind the other; includes rabbits, hares and pikas (Webster 1977).

land base—the amount of land with which the land manager has to work (Thomas 1979).

landing—any place on or adjacent to a logging site where logs are assembled for further transport.

large sawtimber stand condition—a stand condition in the forests of western Oregon and Washington where dominant trees exceed 21 inches d.b.h.

leach—to subject to the action of a percolating liquid such as water.

leachate—a solution or product obtained by leaching.

legume—a plant belonging to the Leguminosae or pea family.

lentic habitats—standing waters such as lakes, ponds, and swamps.

life form—a group of wildlife species whose requirements for habitat are satisfied by similar stand conditions within given plant communities (adapted from Thomas 1979).

livestock—domestic animals, usually ungulates, raised for use, profit, or pleasure (Ford-Robertson 1971).

log decomposition class—any of five stages of deterioration of logs in the forest; stages range from essentially sound to almost total decomposition (adapted from Thomas 1979).

logging—a general term including any or all of these forest harvesting activities: timber falling, yarding, hauling, and road building.

lopping—after felling, the cutting of small trees and branches and tops of large trees so that the resultant slash will lie close to the ground and decay more rapidly (Ford-Robertson 1971).

lopping and scattering—a method of slash disposal in which the woody debris (residue) is spread more or less evenly over the ground; it is not burned (Ford-Robertson 1971).

lotic habitat—flowing waters such as streams and rivers.

MAI—see mean annual increment.

macrohabitat—a large area that provides acceptable or tolerable environmental conditions for a species or a group of species to live.

macrophytic algae—plant forms, individuals of which can be observed with the unaided eye (Proctor et al. 1980).

managed forest—a forest that has been brought under management to accomplish specified objectives, usually increased wood production (Thomas 1979).

marine—of, or pertaining to, the salty waters of the oceans and associated seas of the earth (Proctor et al. 1980).

mass wasting—the downslope movement of soil, rock and organic matter under the influence of gravity; includes landslides, rockslides and debris avalanches (Toews and Brownlee 1981).

mean—average; the total of a series of measurements divided by the number of measurements (Thomas 1979).

mean annual increment (MAI)—the total increment up to a certain age divided by that age (Ford-Robertson 1971).

merchantable snag—a snag containing enough sound wood that its value at the mill exceeds the cost of cutting and transporting it to that location (Thomas 1979).

merchantable tree—a tree containing enough sound wood that its value at the mill exceeds the cost of cutting and transporting it to that location (adapted from Thomas 1979).

microclimate—the climatic conditions within a small or local habitat that is well defined (Hanson 1962).

microhabitat—a small or restricted set of distinctive environmental conditions that constitute a small habitat, such as a tree stump or a space between clumps of grass.

migrant species—wildlife or fish species that move seasonally from one habitat to another.

migration—deliberate movement of animals, birds and fish from one habitat to another. Includes the downstream movement of young salmonids from streams to sea and upstream movement of adult spawners to spawning streams (adapted from Toews and Brownlee 1981).

migration route—a travel route used routinely by wildlife in their seasonal movement from one habitat to another (Thomas 1979).

mitigating measures—specific procedures to reduce or avoid potential impacts of development on the environment.

mitigation—actions to avoid, minimize, reduce, eliminate, or rectify the impact of a management practice (USDA Forest Service 1981e)

mixed conifer forest—a forest community at mid-elevations in southwest Oregon dominated by two or more coniferous species - Douglas-fir, ponderosa pine, sugar pine, incense-cedar and white fir.

monitoring—any and all actions which may be undertaken in order to assess the survival success of a species over time, or to evaluate the results of a management action or activity upon the species' habitat.

monoculture—the raising of a crop of trees consisting of only one species; such crops are usually even-aged.

mortality—in wildlife management, the loss in a population from any cause, including hunter kill, poaching, predation, accident, and disease (Ford-Robertson 1971); in forestry, the trees in a stand that die from various natural causes, animal or insect damage, or man's disturbance (adapted from Thomas 1979).

multilayered canopy—forest stands with two or more distinct tree layers in the canopy; synonymous with multistoried stands (Thomas 1979).

multiple use—a concept of land management in which a number of resources are produced simultaneously from the same land base; such as wood, water, wildlife, recreation, and grazing (adapted from Thomas 1979).

mycorrhizal fungi—fungi which have a symbiotic relationship with the roots of certain plants (Hanson 1962).

nekton—marine animals that are able to swim against normal wave and current action (Proctor et al. 1980).

nest box—a box with an entrance hole into a hollow interior; these boxes, when mounted in the forest, provide nesting and roosting sites primarily for secondary cavity-using species (Thomas 1979).

nitrogen fixation—the conversion of elemental nitrogen (N_2) from the atmosphere to organic combinations or to forms readily utilizable in biological processes (Ford-Robertson 1971).

noncommercial forest—a forest which is not capable of yielding at least 20 cubic feet of wood per acre per year from commercial species, or a forest which is comprised of only noncommercial tree species.

noncommercial thinning—the selective cutting of nonmerchantable saplings and pole-sized trees.

nongame wildlife—all wild terrestrial vertebrates not subject to sport hunting (Thomas 1979).

nonmerchantable—cull material which has no commercial value.

nonsalmonid fish—fish not included in the family Salmonidae.

nutrient cycling—the circulation of elements, such as nitrogen and carbon, via specific pathways from abiotic to biotic portions of the environment and back again; all mineral and nutrient cycles involving man, animals and plants - such as the carbon cycle, phosphorous cycle, and nitrogen cycle (Schwarz et al. 1976).

obligate species—a plant or animal that occurs in a narrowly defined habitat; e.g., tree cavity, rock cave, wet meadow (adapted from Thomas 1979).

old growth—a forest comprised of many large trees, large snags, and numerous large down logs; having a multilayered canopy composed of several tree species; the trees showing signs of decadence; the last stage in forest succession: in western Oregon and Washington forests begin exhibiting old-growth characteristics at about 175 to 250 years of age; the most extensive type of old-growth is the Douglas-fir/western hemlock forest which lives for 350 to 750 years.

open sapling-pole stand condition—a stand condition in the forests of western Oregon and Washington in which the dominant vegetation is trees that qualify as poles or saplings or both, and where the crowns have not closed (adapted from Thomas 1979); saplings are 1 to 4 inches d.b.h.; poles 4 to 9 inches d.b.h., and crown cover does not exceed 60 percent.

optimal cover—habitat for deer and elk which has tree overstory and understory, shrub and herbaceous layers; the overstory canopy generally exceeding 70 percent crown closure and dominant trees generally exceed 21 d.b.h.; provides snow intercept, thermal cover, and maintenance forage.

organism—any living individual of any plant or animal species (Morris 1976).

overstory—the portion of the trees that form the uppermost canopy layer in a forest of more than one story (Ford-Robertson 1971); dominant and codominant trees.

parr—young salmonids rearing in freshwater, usually in their first or second year of life.

partial cut—any timber harvest that removes some trees while leaving others standing for some management purpose (adapted from Thomas 1979).

pelagic—pertaining to the open sea, independent of the coast or bottom (Proctor et al. 1980).

pest—an organism causing or capable of causing damage to a tree, a forest, or a forest product (adapted from Ford-Robertson 1971).

pesticide—a substance intended for controlling insects, rodents, weeds, and other forms of plant or animal life that are considered to be pests.

phylogenetic order—species listed in sequence as to evolutionary development (Thomas 1979).

phytoplankton—suspended aquatic organisms which do not require a solid substrate or attachment and which are able to photosynthesize; usually small to microscopic, may be mobile (Proctor et al. 1980).

plant community—a vegetative complex unique in its combination of plants; occurs in particular locations under particular influences; a reflection or integration of the environmental influences on the site – such as soils, temperature, elevation, solar radiation, slope, aspect, and rainfall (Thomas 1979); as used in this publication: plant associations where composition or structure provide significantly different wildlife habitat characteristics, e.g., herbaceous wetland, conifer/hardwood forest, high temperate coniferous forest.

pole—a young tree, from the time its lower branches begin to die until the time the rate of crown growth begins to slow and crown expansion is noticeable (Ford-Robertson 1971); poles are between 4 and 9 inches d.b.h.

population—a community of individuals that share a common gene pool (Ford-Robertson 1971).

precommercial thinning—the practice of removing some trees of less than merchantable size from a stand so that the remaining trees will grow faster (USDA Forest Service 1981e).

prescribed burning—skillful application of fire to natural fuels under conditions of weather, fuel moisture, soil moisture, etc., that allows confinement of the fire to a predetermined area and produces the intensity of heat and rate of spread to accomplish planned benefits to one or more objectives of silviculture, wildlife management, grazing, or hazard reduction (USDA Forest Service 1956).

primary cavity nesters—wildlife species that excavate cavities in snags (Thomas 1979).

range—in wildlife management, the general area occupied by a particular animal, often on a seasonal basis, such as elk winter range (Thomas 1979); in land classification, all land, including forest land, that produces native forage in contrast to land cultivated for agricultural crops or carrying dense forest (Ford-Robertson 1971).

raptor—any predatory bird – such as a falcon, hawk, eagle, or owl – that has feet with sharp talons or claws adapted for seizing prey and a hooked beak for tearing flesh (Thomas 1979).

redd—a fish spawning nest in river or stream gravel.

regeneration—the renewal of the tree crop by natural or artificial means; also, the young crop (Ford-Robertson 1971).

residence time—the length of time it takes a log of a given species and size to decompose on the forest floor; or with snags, the length of time a snag of a given species and size will remain standing.

resident fish—fish that do not require extended migrations to complete their life cycles.

resident species—the wildlife species commonly found in a specific area; they may be summer residents, winter residents, or all year residents (adapted from Thomas 1979).

riparian—of, relating to, or living on the bank of a river, lake, etc. (Webster 1977).

riparian vegetation—vegetation adapted to moist growing conditions found along waterways and shorelines.

riparian zone, habitat, or area—terrestrial areas where the vegetation and microclimate are influenced by perennial and/or intermittent water, associated high water tables and soils which exhibit some wetness characteristics; this habitat is transitional between true bottom land wetlands and upland terrestrial habitats and, while associated with water courses, may extend inland for considerable distances.

riprap—broken rock, cobbles or boulders placed on the bank of a stream or river for protection against the erosive action of water.

rodent—any of several small mammals characterized by constantly growing incisors adapted for gnawing, such as mice, squirrels, beavers, etc. (Webster 1977).

rodenticide—a substance that kills, repels or controls rodents (Webster 1977).

root wad—the mass of roots, soil, and rocks that remains intact when a tree, shrub, or stump is uprooted; commonly seen on windthrown trees (adapted from Thomas 1979).

rotation—the planned number of years between the regeneration of an even-aged stand and its final cutting at a specified stage (adapted from Ford-Robertson 1971).

rotation age—the age of an even-aged forest stand at final harvest (adapted from Ford-Robertson 1971).

ruminant—any cud-chewing mammal, such as deer or elk – which has a stomach consisting of four divisions (Webster 1977).

salinity—the total amount of dissolved solid material contained in a volume of water, expressed in parts per thousand (ppt) (Proctor et al. 1980).

salmonid habitat—aquatic environments suitable for use by salmonids.

salmonids—fishes within the family Salmonidae; e.g., salmon and trout.

salt marsh—a marsh in which the water is salty or brackish, with salinity greater than freshwater but less than sea water, and containing halophytic (salt-tolerant) vegetation (Proctor et al. 1980).

salvage—the dead, dying, or deteriorating woody material removed from the forest and sold (Thomas 1979).

salvage cutting—the removal and sale of trees that are dead, dying or deteriorating (Ford-Robertson 1971).

sanitation cutting—the removal of dead or damaged trees or trees susceptible to death or damage – usually to prevent the spread of pests or pathogens and so promote forest hygiene (Ford-Robertson 1971).

sapling—a young tree that is no longer a seedling but not yet a pole; a tree between 1 and 4 inches d.b.h.

sapwood—the outer layer of wood in the growing tree which contains living cells and reserve materials; e.g., starch (Ford-Robertson 1971).

sawtimber (coniferous)—trees with a minimum diameter of 9 inches d.b.h. that can produce at least one sawlog 12 feet in length with a minimum top diameter of 6 inches inside bark (adapted from Bassett and Oswald 1981).

scarification—the process of breaking up or loosening compacted soil to assure better penetration of roots of young seedlings, thus assuring greater survival and faster growth for these trees; also, removal of competing vegetation by mechanical means.

secondary cavity nester—wildlife that occupies a cavity in a snag that was excavated by another species (Thomas 1979).

second-growth—forest stands in the process of regrowth after an earlier cutting or disturbance; in common useage it is second-growth that follows removal of old-growth forests.

sediment—any material carried in suspension by water, which will ultimately settle to the bottom (Proctor et al. 1980).

sedimentary rocks—rocks formed by the accumulation of sediment in water or from air (American Geological Institute 1962).

seedling—a young tree grown from seed from the time of germination until it becomes a sapling (Ford-Robertson 1971); seedlings are less than one inch in diameter.

seed tree—any tree retained to provide seed for natural forest regeneration (Ford-Robertson 1971).

selection cutting—the periodic removal of trees, individually or in small groups, from an uneven-aged forest in order to realize the yield and establish a new tree crop (Ford-Robertson 1971).

seral communities or stages—the relative transitory aggregation of plants and animals within a sere; a preclimax stage of succession.

seral species—a species occurring as a member of a seral community and not necessarily occurring in the climax community.

sere—the stages that follow one another in an ecologic succession (Hanson 1962).

shade-tolerant species—plants that grow well in shade (low light intensity) (adapted from Thomas 1979).

shelterwood cutting—any regeneration cutting designed to establish a new tree crop under the protection of remnants of the old stand (Ford-Robertson 1971).

shrub—a plant with persistent woody stems and less than 16 feet tall; usually produces several basal shoots as opposed to a single bole; differs from a tree by its low stature and nonarborescent form (adapted from Kothmann 1974).

shrub stand condition—a stand condition in the forests of western Oregon and Washington in which the vegetation of the stand is dominated by shrubs less than 10 feet tall and less than 30 percent crown cover.

silvicultural methods or practices—techniques used to manipulate forest stands to achieve desirable characteristics.

silvicultural prescription—a written plan of action to carry out silvicultural treatments to produce a desired result in terms of stand composition and condition (Thomas 1979).

silvicultural system—a process which follows accepted silvicultural principles, whereby the tree crops are tended to produce crops of a desired form, harvested, and replaced (Ford-Robertson 1971).

silviculture—the science and art of growing and tending forest crops by controlling the establishment, composition, distribution and representation of tree species, age and/or size classes (USDA Forest Service 1981e).

site—an area considered in terms of its environment, particularly as this determines the type, quality, and growth rate of the potential vegetation (Thomas 1979).

site class—a measure of the relative productive capacity of an area for timber or other vegetation.

site index—a measure of forest site class based on the height of the dominant trees in a stand at an arbitrarily chosen age (Ford-Robertson 1971); west of the Cascade Range in Oregon and Washington this age is 100 years.

site preparation—any action taken in conjunction with a reforestation effort (natural or artificial) to create an environment which is favorable for survival of suitable trees during the first few growing seasons; this environment can be created by altering ground cover, soil, or microsite conditions through the use of biological, mechanical, or manual clearing, prescribed burning, application of herbicides, or a combination of methods.

site specific—on a case-by-case basis.

site-specific conditions—biological and physical components of the environment that occur at any given location.

skyline yarding—a cable yarding system utilizing a spar or tower to provide lift to one end of the logs as they are dragged across the ground to a landing; such systems are capable of yarding for distances up to 2,600 feet; some skyline systems are capable of full-cable suspension.

skyroads—narrow corridors cut through the forest to allow passage of skyline yarding cables and the logs they are transporting; usually used when thinning forest stands.

slash—the residue (branches, bark, tops, cull logs, broken or uprooted trees) left on the ground after logging has been completed; it may be left in place to rot, removed by burning, or hauled away.

smolt—the juvenile life stage of salmon or steelhead trout migrating to the ocean and undergoing physiological changes from a freshwater existence to a saltwater existence.

snag—a standing dead tree.

snag dependent species—birds and animals that are dependent on snags for nesting, roosting or foraging habitat (adapted from Thomas 1979).

snag recruitment—the process by which new snags become available for wildlife use; may be the result of natural mortality or the selection and treatment of living trees.

soft snag—a snag composed primarily of wood in advanced stages of decay and deterioration, generally not merchantable (adapted from Thomas 1979).

softwood—the wood produced by coniferous trees; distinguished from hardwoods by the lack of vessels.

spawning—the act of releasing and fertilizing eggs by fish.

special habitat—a habitat which has special function not provided by plant communities and successional stages; includes riparian zones, estuaries, snags, dead and down woody material, and edges; biological in nature; can be created or altered by management (Thomas 1979).

species—a group of individual plants or animals (including species, subspecies and populations) that live in common spatial arrangement and interbreed.

species specific—wildlife species which occur in areas due to the presence of some life requirements.

spot burning—a modified form of broadcast slash burning in which only the greater accumulations are fired and the fire is confined to these spots (USDA Forest Service 1956).

stand—plant communities, particularly of trees, sufficiently uniform in composition, constitution, age, spatial arrangement, or condition to be distinguishable from adjacent communities; also, may delineate a silvicultural or management entity (Ford-Robertson 1971).

stand condition—the structure of forest stands resulting from timber harvest, fire, or other disturbance, and classified into six conditions similar to successional stages: grass-forb, shrub, open sapling-pole, closed sapling-pole-sawtimber, large sawtimber, and old growth.

standing crop—the total quantity of fish present in a body of water at any particular moment.

stand structure—see structure.

stand treatment—silvicultural practices applied to a forest stand.

stream order—a system of stream classification; each small unbranched tributary is a first-order stream; two first-order streams join to make a second-order stream; a third-order stream has only first- and second-order tributaries, and so forth.

stocking—a loose term for the amount of anything on a given area, particularly in relation to the optimum; more precisely, a measure of the proportion of an area actually occupied by trees, in terms of stocked quadrats or percent canopy closure (Ford-Robertson 1971).

structural diversity—diversity in a forest stand that results from layering or tiering of the canopy; an increase in layering or tiering leads to an increase in structural diversity (Thomas 1979).

structure—the configuration of elements, parts, or constituents of a habitat, plant or animal community or forest stand (adapted from Thomas 1979).

substrate—the surface on which a plant or animal grows or is attached (Proctor et al. 1980); the bottom materials in a lake, stream, or estuary.

subtidal—below the mean low water (tide) level.

succession—the changes in vegetation and in animal life that take place as the plant community evolves from bare ground to climax (Thomas 1979).

successional stage—a stage or recognizable condition of a plant community which occurs during its development from bare ground to climax.

summer range—an area used by deer and elk during the summer months; usually at higher elevation or on north and east exposures.

suppressed trees—trees in a forest stand whose crowns are below the general level of the canopy; growth is inhibited due to competition for a limited resource such as sunlight; such trees are weak, slow-growing, and often become mortality.

sustained yield or production—the yield that a forest can produce continuously from a given intensity of management; implies continuous production; a prime goal is to achieve, at the earliest practical time, a balance between increment and cutting (Ford-Robertson 1971).

symbiosis—a relationship between two or more kinds of living organisms wherein all benefit; sometimes obligatory to one or more of the organisms in the relationship (Ford-Robertson 1971).

sympatric—species which arose or occur together in the same geographical area, but do not rely on each other.

synergistic—two or more substances acting together to produce an effect greater than that of any one of the substances alone.

talus—the accumulation of broken rocks that occurs at the base of cliffs or other steep slopes (Thomas 1979).

target tree—a tree meeting certain size specifications; in uneven-aged management, the greatest height and largest diameter tree desired prior to harvest; in uneven-aged management, target tree size replaces rotation age.

tectonic—relating to deformation of the earth's crust – especially with folding and faulting.

temperate coniferous forests—forests of northwestern North America where the climate is mild and humid; dominated almost totally by coniferous species that grow large in size and attain great age; these stands are highly productive and their biomass accumulation is among the greatest known anywhere; extensive in area; four major vegetation zones are included: Sitka spruce zone and western hemlock zone both occur at lower elevations; Pacific silver fir zone occurs at mid-elevations; mountain hemlock zone occurs at high elevation: the most important coniferous trees represented in these zones are Douglas-fir; several species of hemlocks, true firs, spruces, pines; western redcedar, incense-cedar, Port Orford-cedar and Alaska-cedar; also a plant community described in this handbook (see chapter 2 and appendix 5).

terrestrial ecosystem—a land area, including all the organisms and nonliving components, that functions as a natural interacting system.

territory—the area which an animal defends, usually during breeding season, against intruders of its own species (Hanson 1962).

thermal cover—vegetative cover used by animals to modify the adverse effects of weather (adapted from Thomas 1979); a forest stand that is at least 40 feet in height with tree canopy cover of at least 70 percent.

thinning—felling of part of an immature crop or stand to accelerate growth in the remaining trees; by suitable selection, to improve the form of the trees that remain (Ford-Robertson 1971).

threatened species—a plant or animal species which is likely to become an endangered species in the foreseeable future (throughout all or a significant portion of its range) because its habitat is threatened with destruction, drastic modification, or severe curtailment, or because of overexploitation, disease, predation, or other factors; federally threatened species are officially designated by the U.S. Fish and Wildlife Service and published in the *Federal Register* (adapted from Thomas 1979).

tidal prism—the total amount of water that flows into or out of an estuary, bay, or harbor with the movement of the tide; this volume is a function of the tidal range and the surface area of the estuary, bay, or harbor integrated over the range of the tide (Proctor et al. 1980).

tide—the periodic rise and fall of sea level produced by gravitational forces of the moon and sun acting upon the rotating earth (Proctor et al. 1980).

timber—a general term for forest crops and forest stands.

timber management—the management of the forest to enhance production of wood products for commercial use (Thomas 1979).

torpor—a condition of mental or physical inactivity (Morris 1976).

toxic—poisonous, harmful.

tractor yarding—a method of moving logs across the ground from the point of felling to a central location or landing through use of tracked or wheeled vehicles.

trade-off—an exchange of one thing in return for another; especially a giving up of something desirable, as a benefit or advantage, for something regarded as more desirable (Morris 1976).

travel corridor—a route followed by animals along a belt or band of suitable cover or habitat (Thomas 1979).

treatment—the application of various silvicultural practices to a forest stand.

trophic level—a link in a food chain; one of the parts of a nutritive series in an ecosystem in which a group of organisms in a certain stage in the food chain secures food in the same general manner. The first or lowest trophic level consists of producers (usually green plants); the second level, of herbivores (primary consumers); and the third level, of primary carnivores (secondary consumers); bacteria and fungi are organisms in the decomposer trophic level.

true fir—any of several members of the genus Abies; e.g., grand fir, *Abies grandis* (Douglas-fir, *Pseudotsuga menziesii*, is not a true fir).

turbid—muddy or cloudy water (Webster 1977).

turbidity—the state of conditions of having the transparence or translucence disturbed, as when sediment in water is stirred up (Proctor et al. 1980).

two-storied stand—a stand of trees whose crown structure is divided into two distinct canopy layers (Thomas 1979).

type—(also see habitat type) a site classified qualitatively by its climate, soil, or vegetation (Ford-Robertson 1971); in forestry, usually based on the dominant tree species (Thomas 1979).

underburning—the prescribed use of fire to burn the vegetation under a forest canopy but without burning the canopy (Thomas 1979).

understory—vegetation (trees, shrubs, herbs) growing under the canopy formed by taller trees (adapted from Ford-Robertson 1971).

uneven-aged stand—a forest stand, natural or managed, containing a mix of trees that differ markedly in age (adapted from Ford-Robertson 1971).

ungulate—a mammal with hooves (Hanson 1962).

unique habitats—(also see special habitat) wildlife habitats (i.e., cliffs, caves, and talus) of special function not included within plant communities and successional stages or special habitats; geomorphic in nature (Thomas 1979).

unmanaged forest—a forest in which no management is presently occurring; e.g., a naturally occurring forest; an unmanaged forest may have been managed in the past or may be managed in the future (adapted from Thomas 1979).

vascular plants—higher level plants having conducting tissue for the movement of water, nutrients, and food materials as compared to nonvascular plants where all life functions must be carried out in each cell.

vertebrate—an animal having a spinal column.

viable population—a wildlife population of sufficient size to maintain its existence over time in spite of normal fluctuations in population levels (Thomas 1979).

volume—the quantity of measurable wood fiber in a tree or a stand of trees.

water column habitat—the space between the surface and the bottom of a body of water.

westside—referring to the geographical area west of the summit of the Cascade Range in Oregon and Washington.

wetlands—lands which are covered by shallow water or are periodically saturated with the water table at, near, or above the soil surface; these areas commonly have hydric soils and usually support the growth of hydrophytes.

wildlife—all nondomesticated vertebrates (Thomas 1979).

wildlife habitat—habitat suitable for designated wildlife species or groups of species (Thomas 1979).

wildlife tree—a live tree, partially dead tree, or a snag in a forest, riparian zone or in a cutting unit that is left (reserved) for wildlife habitat.

windrow—forest residue (slash) piled in a long row so as to facilitate burning and/or clearing the ground for reforestation.

windthrow—(see blowdown).

winter range—an area used by deer and elk during the winter months; usually at lower elevation and/or on south and west exposures.

wood fiber—the woody material produced in the trunk and branches of a tree without designation as to the end product for which it will be used.

yarding—transporting logs (timber) from the point of felling to a landing (Ford-Robertson 1971).

yarding system—the method by which logs are transported from the point of felling to a landing; commonly used systems include: tractor (cat), high-lead, skyline, helicopter, balloon, and horses.

yield table—tabular data that shows the growth pattern for one or more tree species in a forest stand; derived from measurements at intervals covering the stand's life; includes mean d.b.h. and tree height, number of stems, and standing wood volume per unit area; may include volume of thinnings, main crop, or total volume (adapted from Ford-Robertson 1971).

zooplankton—aquatic animals, or protists (single-celled organisms) which cannot actively swim against the current and which cannot make their own food by photosynthesis; includes many larval forms of otherwise nonplanktonic organisms (Proctor et al. 1980).

Photo Credits

The photographs are used courtesy of the following organizations and individuals:

CHAPTER 1. Introduction

Fig. 1—USDA Forest Service by Reade Brown. Fig. 2—Fred Martinsen. Fig. 3—Washington Department of Game. Figs. 4 and 5—USDA Forest Service by Reade Brown. Fig. 7—USDA Forest Service by Ray Scharpf. Fig. 8—USDA Forest Service by Reade Brown. Fig. 10—Washington Department of Game. Fig. 13—Weyerhaeuser Company. Fig. 15—Washington Department of Game.

CHAPTER 2. Plant Communities and Stand Conditions

Figs. 3, 4, 5, and 6—USDA Forest Service by Fred Hall. Fig. 7—USDA Forest Service by Reade Brown. Fig. 8—USDA Forest Service by Fred Hall. Fig. 10—USDA Forest Service by Ray Scharpf. Figs. 11 and 12—USDA Forest Service by Fred Hall. Fig. 13—USDA Forest Service by Reade Brown. Figs. 14, 15, and 17—USDA Forest Service by Fred Hall.

CHAPTER 3. Wildlife Relationships to Plant Communities and Stand Conditions

Fig. 1—Oregon Department of Fish and Wildlife. Fig. 2—Al St. John. Fig. 3—Oregon Department of Fish and Wildlife. Fig. 4—copyright: Tomas Black. Fig. 5—Oregon Department of Fish and Wildlife by Ron Rohweder. Fig. 6—Oregon Department of Fish and Wildlife by Jim Collins. Figs. 8 and 9—Oregon Department of Fish and Wildlife. Fig 13—Washington Department of Game. Fig. 14—Robert M. Storm.

CHAPTER 4. Riparian Zones and Freshwater Wetlands

Figs. 3A, 3B, 3C, 5A, 5B, and 5C—Washington Department of Game. Fig. 5D—Jerry Mires. Fig. 6A—Washington Department of Game. Fig. 6B—Reade Brown. Fig. 8—Robert Borovicka. Fig. 9—U.S. Department of the Interior, Geological Survey. Fig. 11—U.S. Department of the Interior, Bureau of Land Management by John Anderson. Figs. 12 and 13A—U.S. Department of the Interior, Bureau of Land Management. Fig. 13B—Jerry Mires.

CHAPTER 5. Estuaries

Fig. 4—Washington Department of Game. Fig. 6—copyright: John Fundskar. Figs. 17 and 18—Tom Gaumer. Fig. 20—Washington Department of Game by Larry Brewer. Fig. 23—U.S. Army, Corps of Engineers. Fig. 24—Washington Department of Game by Larry Brewer. Fig. 25—Tom Gaumer. Fig. 26—Washington Department of Game by Larry Brewer. Fig. 27—Tom Gaumer. Fig. 28—Rick Starr.

CHAPTER 6. Edges

Figs. 1, 2, and 9—Alan Curtis. Fig. 11—Wayne Logan. Fig. 14—Alan Curtis. Fig. 17—Gene Herb.

CHAPTER 7. Snags

Figs. 1, 2A, 2B, 3A, 3B, 3C, 4, 6, 9, and 10—William Nietro. Fig. 12—Charles Telford. Figs. 15, 16, 17, and 22—William Nietro.

CHAPTER 8. Dead and Down Woody Material

Fig. 3—Jerry Mires. Figs. 4, 7, 8, 9, and 10—Oregon Department of Fish and Wildlife.

CHAPTER 9. Caves, Cliffs, and Talus

Figs. 3, 5, and 6—copyright: Charlie and Jo Larson. Fig. 7—Fred Dobler. Fig. 8—Washington Department of Game. Figs. 9, 10, and 11—USDA Forest Service by Ray Scharpf. Fig. 12—Weyerhaeuser Company.

CHAPTER 10. Salmonids

Figs. 2 and 3—USDA Forest Service by Reade Brown. Fig. 4—USDA Forest Service. Fig. 5—Oregon Department of Fish and Wildlife. Figs. 7 and 8—USDA Forest Service. Fig. 9—Oregon Department of Fish and Wildlife. Fig. 10—USDA Forest Service. Fig. 11—Oregon Department of Fish and Wildlife. Fig. 23—USDA Forest Service. Fig. 25—Fred Everest. Figs. 27, 28, and 29—USDA Forest Service.

CHAPTER 11. Deer and Elk

Fig. 1—Reade Brown. Fig. 2—Washington Department of Game. Figs. 4 and 6—USDA Forest Service by Ray Scharpf. Fig. 10—Reade Brown. Fig. 11—USDA Forest Service by Reade Brown. Fig. 12—USDA Forest Service by Ed Harshman. Fig. 13—USDA Forest Service by Reade Brown. Figs. 15, 17, 19A, and 19B—USDA Forest Service by Ray Scharpf. Fig. 20—Reade Brown. Fig. 23—Weyerhaeuser Company. Fig. 24—USDA Forest Service by Ray Scharpf. Figs. 25A, 25B, 27, 28, and 29—Reade Brown.

CHAPTER 12. Northern Spotted Owls

Figs. 2, 4, and 6—Eric Forsman.

CHAPTER 13. Bald Eagles

Fig. 1—Mark Stalmaster. Fig. 4—Teryl Grubb. Figs. 7 and 8—Mark Stalmaster. Fig. 9A—Richard Knight. Fig. 9B—Teryl Grubb. Fig. 9C—Richard Knight.

CHAPTER 14. Silvicultural Options

Figs. 1, 2, and 5—USDA Forest Service by Fred Hall.

CHAPTER 15. Impacts on Wood Production

Fig. 1—Alan Curtis. Fig. 2—USDA Forest Service by Reade Brown.

Index

This index is designed to be used in conjunction with the tables of contents preceeding each chapter. Appendices have not been indexed, nor have the examples of appendix tables in chapter 3.